# Bacteria TMDL Development for Hyco River, Aarons Creek, Little Buffalo Creek, and Beech Creek Located in Halifax and Mecklenburg Counties, Virginia

Submitted to:
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# EXECUTIVE SUMMARY

This report addresses the impaired segments in the Hyco River, Aarons Creek, Beech Creek, and Little Buffalo Creek watersheds listed on the 2012 Impaired Waters - 303(d) List for recreation use due to exceedances of the criteria for *Escherichia coli* (*E. coli*) bacteria. As shown in Table E.1 and Figure E.1, the impaired segments located in the Hyco River watershed include: Big Bluewing Creek (VAC-L74R_BLU01A08), Coleman Creek (VAC-L74R_CLB01A06), Little Coleman Creek (VAC-L74R_LOL01A06), and Hyco River (VAC-L74R_HYC02A06 and VAC-L74R_HYC01A00). The impaired segments in the Aarons Creek watershed include: Aarons Creek (VAC-L73R_AAR01A00) and North Fork Aarons Creek (VAC-L73R_NFA01A06). The impaired segment in the Little Buffalo Creek watershed is Little Buffalo Creek (VAC-L76R_LFF01A00). The impaired segment in the Beech Creek watershed is Beech Creek (VAC-L75R_BEE01A98).

*Table E.1. Summary of Impairments in the TMDL Watersheds.*

| TMDL Watershed | Impaired Segment | 305b Segment ID | Year First Listed |
|---|---|---|---|
| Aarons Creek | Aarons Creek | VAC-L73R_AAR01A00 | 2010 |
| | North Fork Aarons Creek | VAC-L73R_NFA01A06 | 2012 |
| Hyco River | Hyco River | VAC-L74R_HYC02A06 | 2006 |
| | Hyco River | VAC-L74R_HYC01A00 | 2008 |
| | Little Coleman Creek | VAC-L74R_LOL01A06 | 2008 |
| | Coleman Creek | VAC-L74R_CLB01A06 | 2008 |
| | Big Bluewing Creek | VAC-L74R_BLU01A08 | 2008 |
| Beech Creek | Beech Creek | VAC-L75R_BEE01A98 | 2008 |
| Little Buffalo Creek | Little Buffalo Creek | VAC-L76R_LFF01A00 | 2004 |

## Description of the Study Area

Located between Richmond, Virginia, and Raleigh, North Carolina, the area studied in this report spans through Halifax County and Mecklenburg County in Virginia, as well as Person County, and Granville County in North Carolina. The boundary area lies primarily south of U.S. Route 360/ Philpott Road and U.S. 58/Bill Tuck Highway and north of US Route 158 (Oxford Road).

## Impairment Description

Hyco River segments VAC-L74R_HYC02A06 and VAC-L74R_HYC01A00 were first identified as impaired on the Virginia Department of Environmental Quality (VADEQ)'s 303(d) list due to exceedances of the state's water quality criteria for *E. coli* bacteria in 2006 and 2008, respectively. The two segments together extend for 23.16 miles, beginning at the confluence with Castle Creek and continuing downstream to its mouth on the Dan River.

Aarons Creek (VAC-L73R_AAR01A00) was first identified as impaired on VADEQ's 2010 303(d) List due to exceedances of the state's water quality criteria for *E. coli* bacteria. The segment extends for 5.03 miles, beginning at the confluence with Big Branch and continuing downstream to its mouth on the Dan River.

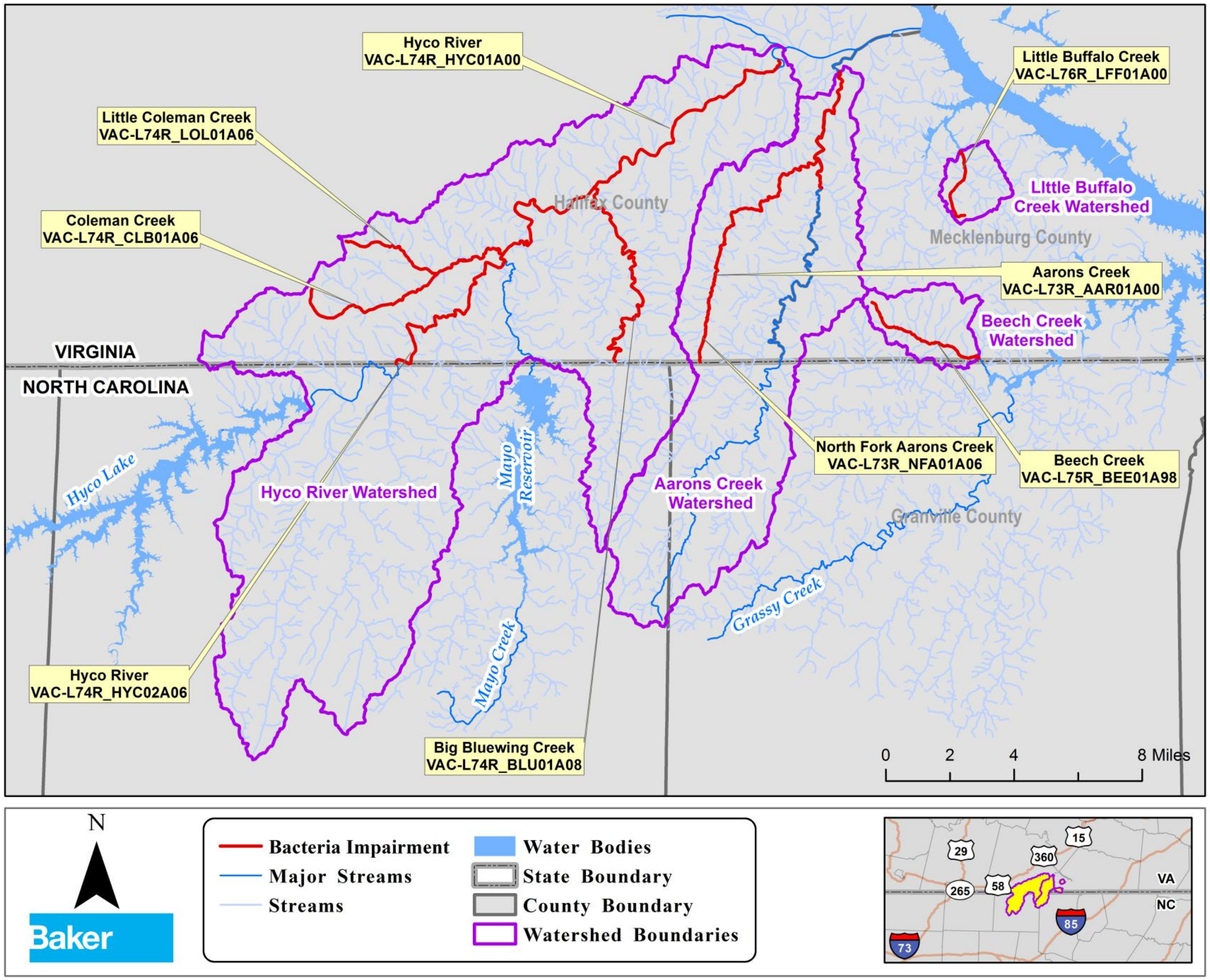


*Figure E.1. Impaired Segments in the Hyco River, Aarons Creek, Beech Creek and Little Buffalo Creek TMDL Watersheds.*

North Fork Aarons Creek (VAC-L73R_NFA01A06) was first identified as impaired on VADEQ's 2012 303(d) List due to exceedances of the state's water quality criteria for *E. coli* bacteria. The segment extends for 9.43 miles, beginning at its headwaters and continuing downstream to its mouth on Aarons Creek.

Coleman Creek (VAC-L74R_CLB01A06) was first identified as impaired on VADEQ's 2008 303(d) List due to exceedances of the state's water quality criteria for *E. coli* bacteria. The segment extends for 8.42 miles, beginning at its headwaters and continuing downstream to its mouth on the Hyco River.

Little Coleman Creek (VAC-L74R_LOL01A06) was first identified as impaired on VADEQ's 2008 303(d) List due to exceedances of the state's water quality criteria for *E. coli* bacteria. The segment extends for 3.45 miles, beginning at its headwaters and continuing downstream to its mouth on Coleman Creek.

Beech Creek (VAC-L75R_BEE01A98) was first identified as impaired on VADEQ's 2008 303(d) List due to exceedances of the state's water quality criteria for *E. coli* bacteria. The segment extends for 4.29 miles, beginning at its headwaters to about 3,300 feet (~0.6 miles) above its confluence with the Roanoke River.

Little Buffalo Creek (VAC-L76R_LFF01A00) was first identified as impaired on VADEQ's 2002 303(d) List due to exceedances of the state's water quality criteria for fecal coliform bacteria. It was also listed in 2004 303 (d) list due to exceedances for the state's water quality criteria for *E. coli* bacteria. The segment extends for 2.55 miles, beginning at its headwaters and continuing downstream to its mouth on the Roanoke River.

Big Bluewing Creek (VAC-L74R_BLU01A08) was first identified as impaired on VADEQ's 2008 303(d) List due to exceedances of the state's water quality criteria for *E. coli* bacteria. The segment extends for 9.66 miles, beginning about 4,700 feet (~0.9 miles) below it confluence with Bredlov Creek and continuing downstream to its mouth on the Hyco River.

## Applicable Water Quality Standards

Water quality standards consist of designated uses for a waterbody and water quality criteria necessary to support those designated uses. According to Virginia Water Quality Standards (9 VAC 25-260-5), the term "water quality standards" means "provisions of state or federal law which consist of a designated use or uses for the waters of the Commonwealth and water quality criteria for such waters based upon such uses. Water quality standards are to protect the public health or welfare, enhance the quality of water and serve the purposes of the State Water Control Law (§62.1-44.2 et seq. of the Code of Virginia) and the federal Clean Water Act (33 USC §1251 et seq.)."

VADEQ specifies the following criteria for recreational uses (VADEQ, 2011) of waterbodies located in freshwater:

- *E. coli* bacteria shall not exceed a monthly geometric mean of 126 colony forming units (CFU) per 100mL of freshwater or if there are insufficient data to calculate monthly geometric means in freshwater, no more than 10% of the total samples in the assessment period shall exceed 235 CFU/100 mL.

## Watershed Characterization

The Hyco River watershed is approximately 107,239 acres and covers portions of Person and Granville Counties, North Carolina, and Halifax County, Virginia. The Aarons Creek watershed encompasses portions of Halifax County and Mecklenburg County in Virginia and a small portion of Granville County, North Carolina. It is approximately 42,470 acres. The Little Buffalo Creek watershed is located completely within Mecklenburg County, Virginia and is approximately 2,385 acres. The Beech Creek watershed which contains Beech Creek (L75R-03-BAC) is primarily located in Mecklenburg County, Virginia and a small portion of Granville County, Virginia. It covers approximately 4,219 acres

All four watersheds have a high percentage of B soils which are sandy loam soils with moderately fine to moderately coarse textures. They have a moderate infiltration rate when throroughly wet. In particular, Beech Creek watershed and Little Buffalo Creek are composed of 70% and 94%, respectively, of B soils. The Hyco River watershed and Aarons Creek watershed also have high amounts of group C soils which are typically silty-loam sands with an impending layer, and have a slow infilitration rate when thoroughly wetted. Group D soils are also prominent within the low-lying areas of the Hyco River, Aarons Creek,and Beech Creek watersheds. Group D soils include clay soils with a high runoff potential and very slow infiltration rate when thoroughly wetted.

The Hyco River, Aarons Creek, and Beech Creek watersheds consist primarily of forested lands and some pasture lands. Little Buffalo Creek watershed is equally comprised of pasture and forested lands. The climate in the region is characterized by warm, long summers and cool, short winters.

Potential sources of bacteria include runoff from grazing livestock, agricultural practices, wildlife, human waste, and pet waste. Some of these sources are driven by dry weather and others are driven by wet weather. The potential bacteria sources in the watershed were identified and characterized and were found to include permitted facilities, runoff from livestock waste, direct livestock deposition, wildlife, residential waste and pets.

Based on data obtained from VADEQ, there are 4 permitted facilities holding VPDES permits and 23 residences holding domestic permits for discharging into the watershed. An inventory of agricultural practices (livestock population), wildlife and pets was collected from data provided by the 2007 Agricultural Census, the Virginia Department of Game and Inland Fisheries (VDGIF), the American Veterinary Medical Association (AVMA), and from other sources.

## TMDL Technical Approach

The Hydrologic Simulation Program-Fortran (HSPF) model (Bicknell et al., 2001; Duda et al., 2001) was selected and used as a tool to predict the instream water quality conditions under varying scenarios of rainfall and bacteria loading from various point and nonpoint sources within the delineated watersheds. The results from the model were used to develop the TMDL allocations and the required reductions to meet the water quality standard.

Four separate HSPF watershed models were developed for the four groups of impaired segments, namely:

i. The Hyco River watershed including the Hyco River and Coleman Creek, Little Coleman Creek and Big Bluewing Creek
ii. Aarons Creek watershed including Aarons Creek and North Fork Aarons Creek
iii. Little Buffalo Creek watershed including Little Buffalo Creek
iv. Beech Creek watershed including Beech Creek

The watershed models were developed to simulate fate and transport of fecal coliform bacteria because significant data and literature information are available to characterize the accumulation and wash-off of fecal coliform from various nonpoint sources. The modeled fecal coliform concentrations are converted to estimates of *E. coli* concentrations using the following equation as recommended by VADEQ:

$$\log_2 EC = -0.0172 + 0.91905 * \log_2 FC$$

Where, EC = *E. coli* concentration (count/100 mL) and FC = Fecal coliform bacteria concentration (count/100 mL)

Each of the four modeled watersheds was delineated to include several subwatersheds. The watershed delineation was based on a Digital Elevation Model (DEM) and stream reaches obtained from the National Hydrography Dataset (NHD). The number of delineated subwatersheds in the Hyco River, Aarons Creek, Beech Creek, and Little Buffalo Creek watersheds are 71, 40, 15, and 13, respectively. Stream flow data were obtained from the U.S. Geological Survey (USGS) and water quality data were obtained from VADEQ. Weather data were obtained from the National Climatic Data Center (NCDC, 2013).

The period of 2009 to 2012 was used for HSPF hydrologic calibration and 2005 to 2008 was used to validate the HSPF model. The hydrologic calibration parameters were adjusted until there was a good agreement between the observed and simulated stream flow, thereby indicating that the model parameterization was representative of the hydrologic characteristics of the watershed.

## TMDL Calculations

The Total Maximum Daily Load (TMDL) represents the maximum amount of a pollutant that the stream can contain without exceeding the water quality standard. The load allocation for the selected scenarios was calculated using the following equation:

$$TMDL = \Sigma\ WLA + \Sigma\ LA + MOS$$

Where,

WLA = waste load allocation (point source contributions);
LA = load allocation (non-point source allocation); and
MOS = margin of safety.

A required component of the TMDL, the margin of safety (MOS) is used to account for any lack of knowledge concerning the relationship between effluent limitations and water quality. The MOS was implicitly incorporated into this TMDL. Implicitly incorporating the MOS will require that allocation scenarios be designed to meet the monthly geometric mean criterion of 126 cfu/100 mL for *E. coli* bacteria. In addition, it is required that final allocation scenarios be designed so that there is no more than a 10% exceedance rate of the single sample maximum criterion for *E. coli* of 235 cfu/100 mL.

Typically, there are several potential allocation strategies that would achieve the TMDL endpoint and water quality standards. A number of load allocation scenarios were developed to determine the final TMDL load allocation scenario.

Based on the load-allocation scenario analyses, the TMDL allocation plans that will meet the calendar-month *E. coli* geometric mean water quality criterion of 126 cfu/100 mL and the *E. coli* single sample maximum criterion of 235 cfu/100 mL are presented in **Tables E.2 to E.5**.

***Table E.2. Annual Average E. coli Load under Existing Conditions and TMDL Allocation for Hyco River.***

| Bacterial Source | Annual Average *E. coli* Loads (cfu/year) | | Reduction % |
|---|---|---|---|
| | Existing Condition | Allocation | |
| Developed Urban | 2.61E+13 | 1.31E+13 | 50 |
| Crop | 1.15E+10 | 1.15E+10 | 0 |
| Forest | 1.55E+12 | 1.55E+12 | 0 |
| High Residential | 4.27E+11 | 2.14E+11 | 50 |
| Medium Residential | 8.31E+11 | 4.16E+11 | 50 |
| Low Residential | 2.03E+12 | 1.02E+12 | 50 |
| Pasture and Hay | 2.52E+14 | 1.01E+14 | 60 |
| Wetland | 8.99E+12 | 8.99E+12 | 0 |
| Barren Land | 1.35E+12 | 1.35E+12 | 0 |
| Point Sources | 5.81E+10 | 5.81E+10 | 0 |
| Direct Deposition from Cattle | 1.10E+13 | 1.10E+11 | 99 |
| Direct Deposition from Wildlife | 5.11E+12 | 5.11E+12 | 0 |
| Human Sources[1] | 2.22E+11 | 0.00E+00 | 100 |
| Future Growth | 0.00E+00 | 2.66E+12 | |
| Total | 3.13E+14 | 1.36E+14 | 56.7 |

[1]Human sources are failed septic systems and straight pipes

**Table E.3. Annual Average E. coli Load under Existing Conditions and TMDL Allocation for Aarons Creek.**

| Bacterial Source | Average Annual *E. coli* loads (cfu/year) | | Reduction % |
|---|---|---|---|
| | Existing Condition | Allocation | |
| Developed Urban | 4.57E+12 | 3.20E+12 | 30 |
| Crop | 6.61E+09 | 6.61E+09 | 0 |
| Forest | 7.08E+11 | 7.08E+11 | 0 |
| Medium Residential | 1.69E+11 | 1.18E+11 | 30 |
| Low Residential | 5.14E+11 | 5.14E+11 | 0 |
| Pasture and Hay | 8.60E+12 | 5.16E+12 | 40 |
| Wetland | 3.80E+12 | 3.80E+12 | 0 |
| Barren Land | 2.99E+09 | 2.99E+09 | 0 |
| Point Sources | 7.66E+10 | 7.66E+10 | 0 |
| Direct Deposition from Cattle | 3.24E+12 | 1.62E+11 | 95 |
| Direct Deposition from Wildlife | 2.63E+11 | 2.63E+11 | 0 |
| Human Sources[1] | 1.13E+11 | 0.00E+00 | 100 |
| Future Growth | 0.00E+00 | 2.80E+11 | |
| Total | 2.21E+13 | 1.43E+13 | 35.2% |

[1]Human sources are failed septic systems and straight pipes

**Table E.4. Annual Average E. coli Load under Existing Conditions and TMDL Allocation for Beech Creek.**

| Bacterial Source | Annual Average *E. coli* Loads (cfu/year) | | Reduction % |
|---|---|---|---|
| | Existing Condition | Allocation | |
| Developed Urban | 8.12E+11 | 8.12E+10 | 90 |
| Crop | 2.86E+09 | 2.86E+09 | 0 |
| Forest | 9.89E+10 | 9.89E+10 | 0 |
| Low Residential | 9.09E+10 | 9.09E+09 | 90 |
| Pasture and Hay | 1.58E+13 | 1.58E+12 | 90 |
| Wetland | 6.01E+11 | 6.01E+11 | 0 |
| Barren Land | 1.57E+10 | 1.57E+10 | 0 |
| Point Sources | 1.74E+09 | 1.74E+09 | 0 |
| Direct Deposition from Cattle | 6.75E+11 | 6.75E+09 | 99 |
| Direct Deposition from Wildlife | 5.46E+10 | 3.82E+10 | 30 |
| Human Sources[1] | 5.46E+10 | 0.00E+00 | 100 |
| Future Growth | | 4.88E+10 | |
| Total | 1.83E+13 | 2.49E+12 | 86.4 |

[1]Human sources are failed septic systems and straight pipes

*Table E.5. Annual Average E. coli Load under Existing Conditions and TMDL Allocation for Little Buffalo Creek.*

| Bacterial Source | Annual Average *E. coli* Loads (cfu/year) | | Reduction % |
|---|---|---|---|
| | Existing Condition | Allocation | |
| Developed Urban | 8.91E+11 | 6.24E+10 | 93 |
| Crop | 1.91E+09 | 1.91E+09 | 0 |
| Forest | 3.34E+10 | 3.34E+10 | 0 |
| Medium Residential | 2.65E+11 | 1.86E+10 | 93 |
| Low Residential | 9.86E+11 | 6.90E+10 | 93 |
| Pasture and Hay | 8.87E+12 | 6.21E+11 | 93 |
| Wetland | 9.79E+11 | 9.79E+11 | 0 |
| Point Sources | 6.09E+10 | 6.09E+10 | 0 |
| Direct Deposition from Cattle | 1.47E+12 | 1.47E+10 | 99 |
| Direct Deposition from Wildlife | 2.80E+11 | 8.40E+10 | 70 |
| Human Sources[1] | 4.01E+10 | 0.00E+00 | 100 |
| Future Growth | | 3.89E+10 | |
| Total | 1.39E+13 | 1.98E+12 | 85.7 |

[1]Human sources are failed septic systems and straight pipes

The summaries of the bacteria TMDL allocation plan loads are presented in the following tables. The bacteria TMDLs for the Hyco River are presented in **Table E.6**.

*Table E.6. Hyco River TMDL (cfu/year) for E. coli.*

| Impairment | WLA[1] | LA | MOS | TMDL | Existing Load | Percent Reduction |
|---|---|---|---|---|---|---|
| Hyco River (VAC-L74R_HYC01A00, VAC-L74R_HYC02A06) Big Bluewing Creek (VAC-L74R_BLU01A08) Coleman Creek (VAC-L74R_CLB01A06) Little Coleman Creek (VAC-L74R_LOL01A06) | 2.72E+12 | 1.33E+14 | Implicit | 1.36E+14 | 3.13E+14 | 56.7% |
| VA0091804[1] | 2.09E+10 | | | | | |
| VA0022691[1] | 1.46E+10 | | | | | |
| VAG407293[1] | 1.74E+09 | | | | | |
| VAG404089[1] | 1.74E+09 | | | | | |
| VAG407242[1] | 1.74E+09 | | | | | |
| VAG407241[1] | 1.74E+09 | | | | | |
| VAG407238[1] | 1.74E+09 | | | | | |
| VAG404179[1] | 1.74E+09 | | | | | |
| VAG404045[1] | 1.74E+09 | | | | | |
| VAG407229[1] | 1.74E+09 | | | | | |

| Impairment | WLA[1] | LA | MOS | TMDL | Existing Load | Percent Reduction |
|---|---|---|---|---|---|---|
| VAG407257[1] | 1.74E+09 | | | | | |
| VAG407339[1] | 1.74E+09 | | | | | |
| VAG404014[1] | 1.74E+09 | | | | | |
| VAG407239[1] | 1.74E+09 | | | | | |
| VAG404044[1] | 1.74E+09 | | | | | |
| Future Growth[2] | 2.66E+12 | | | | | |

[1]Any issued permit will include bacteria effluent limits in accordance with applicable permit guidance and will ensure the discharge meets the applicable numeric water quality criteria for bacteria at the end-of-pipe.
[2]The WLA reflects an allocation for potential future permits issued for bacteria control.

The bacteria TMDLs for Aarons Creek are presented in **Table E.7**.

*Table E.7. Aarons Creek TMDL (cfu/year) for E. coli.*

| Impairment | WLA[1] | LA | MOS | TMDL | Existing Load | Percent Reduction |
|---|---|---|---|---|---|---|
| Aarons Creek (VAC-L73R_AAR01A00) North Fork Aarons Creek (VAC-L73R_NFA01A06) | 3.57E+11 | 1.39E+13 | Implicit | 1.43E+13 | 2.21E+13 | 35.2% |
| VA0076830[1] | 6.09E+10 | | | | | |
| VAG407266[1] | 1.74E+09 | | | | | |
| VAG407249[1] | 1.74E+09 | | | | | |
| VAG407236[1] | 1.74E+09 | | | | | |
| VAG404093[1] | 1.74E+09 | | | | | |
| VAG407206[1] | 1.74E+09 | | | | | |
| VAG404024[1] | 1.74E+09 | | | | | |
| VAG407255[1] | 1.74E+09 | | | | | |
| VAG404011[1] | 1.74E+09 | | | | | |
| VAG407351[1] | 1.74E+09 | | | | | |
| Future Growth[2] | 2.80E+11 | | | | | |

[1]Any issued permit will include bacteria effluent limits in accordance with applicable permit guidance and will ensure the discharge meets the applicable numeric water quality criteria for bacteria at the end-of-pipe.
[2]The WLA reflects an allocation for potential future permits issued for bacteria control.

The bacteria TMDLs for Beech Creek are presented in **Table E.8**.

*Table E.8. Beech Creek TMDL (cfu/year) for E. coli.*

| Impairment | WLA[1] | LA | MOS | TMDL | Existing Load | Percent Reduction |
|---|---|---|---|---|---|---|
| Beech Creek (VAC-L75R_BEE01A98) | 5.06E+10 | 2.44E+12 | Implicit | 2.49E+12 | 1.83E+13 | 86.4% |
| VAG407314[1] | 1.74E+09 | | | | | |
| Future Growth[2] | 4.88E+10 | | | | | |

[1]Any issued permit will include bacteria effluent limits in accordance with applicable permit guidance and will ensure the discharge meets the applicable numeric water quality criteria for bacteria at the end-of-pipe.
[2]The WLA reflects an allocation for potential future permits issued for bacteria control.

The bacteria TMDLs for Little Buffalo Creek are presented in **Table E.9**.

*Table E.9. Little Buffalo Creek TMDL (cfu/year) for E. coli.*

| Impairment | WLA[1] | LA | MOS | TMDL | Existing Load | Percent Reduction |
|---|---|---|---|---|---|---|
| Little Buffalo Creek (VAC-L76R_LFF01A00) | 9.98E+10 | 1.88E+12 | Implicit | 1.98E+12 | 1.39E+13 | 85.7% |
| VA0062421[1] | 6.09E+10 | | | | | |
| Future Growth[2] | 3.89E+10 | | | | | |

[1]Any issued permit will include bacteria effluent limits in accordance with applicable permit guidance and will ensure the discharge meets the applicable numeric water quality criteria for bacteria at the end-of-pipe.
[2]The WLA reflects an allocation for potential future permits issued for bacteria control.

## Expression of Maximum Daily Loads

**Tables E.10 to E13** show the TMDL expression as daily load following USEPA (2007) guidance for Hyco River, Aarons Creek, Beech Creek, and Little Buffalo Creek, respectively.

*Table E.10. Hyco River TMDL (cfu/day) for E. coli.*

| Impairment | WLA[1] | LA | MOS | TMDL | Existing Load | Percent Reduction |
|---|---|---|---|---|---|---|
| Hyco River (VAC-L74R_HYC01A00, VAC-L74R_HYC02A06) Big Bluewing Creek (VAC-L74R_BLU01A08) Coleman Creek (VAC-L74R_CLB01A06) Little Coleman Creek (VAC-L74R_LOL01A06) | 2.78E+10 | 1.36E+12 | Implicit | 1.39E+12 | 3.17E+12 | 56.3% |
| VA0091804[1] | 2.14E+08 | | | | | |
| VA0022691[1] | 1.50E+08 | | | | | |
| VAG407293[1] | 1.78E+07 | | | | | |
| VAG404089[1] | 1.78E+07 | | | | | |

| Impairment | WLA[1] | LA | MOS | TMDL | Existing Load | Percent Reduction |
|---|---|---|---|---|---|---|
| VAG407242[1] | 1.78E+07 | | | | | |
| VAG407241[1] | 1.78E+07 | | | | | |
| VAG407238[1] | 1.78E+07 | | | | | |
| VAG404179[1] | 1.78E+07 | | | | | |
| VAG404045[1] | 1.78E+07 | | | | | |
| VAG407229[1] | 1.78E+07 | | | | | |
| VAG407257[1] | 1.78E+07 | | | | | |
| VAG407339[1] | 1.78E+07 | | | | | |
| VAG404014[1] | 1.78E+07 | | | | | |
| VAG407239[1] | 1.78E+07 | | | | | |
| VAG404044[1] | 1.78E+07 | | | | | |
| Future Growth[2] | 2.72E+10 | | | | | |

[1]Any issued permit will include bacteria effluent limits in accordance with applicable permit guidance and will ensure the discharge meets the applicable numeric water quality criteria for bacteria at the end-of-pipe.
[2]The WLA reflects an allocation for potential future permits issued for bacteria control.

**Table E.11. Aarons Creek TMDL (cfu/day) for E. coli.**

| Impairment | WLA[1] | LA | MOS | TMDL | Existing Load | Percent Reduction |
|---|---|---|---|---|---|---|
| Aarons Creek (VAC-L73R_AAR01A00) North Fork Aarons Creek (VAC-L73R_NFA01A06) | 3.77E+09 | 1.47E+11 | Implicit | 1.51E+11 | 2.33E+11 | 35.2% |
| VA0076830[1] | 6.45E+08 | | | | | |
| VAG407266[1] | 1.84E+07 | | | | | |
| VAG407249[1] | 1.84E+07 | | | | | |
| VAG407236[1] | 1.84E+07 | | | | | |
| VAG404093[1] | 1.84E+07 | | | | | |
| VAG407206[1] | 1.84E+07 | | | | | |
| VAG404024[1] | 1.84E+07 | | | | | |
| VAG407255[1] | 1.84E+07 | | | | | |
| VAG404011[1] | 1.84E+07 | | | | | |
| VAG407351[1] | 1.84E+07 | | | | | |
| Future Growth[2] | 2.96E+09 | | | | | |

[1]Any issued permit will include bacteria effluent limits in accordance with applicable permit guidance and will ensure the discharge meets the applicable numeric water quality criteria for bacteria at the end-of-pipe.
[2]The WLA reflects an allocation for potential future permits issued for bacteria control.

Table E.12. Beech Creek TMDL (cfu/day) for E. coli

| Impairment | WLA[1] | LA | MOS | TMDL | Existing Load | Percent Reduction |
|---|---|---|---|---|---|---|
| Beech Creek (VAC-L75R_BEE01A98) | 4.55E+08 | 2.20E+10 | Implicit | 2.24E+10 | 1.64E+11 | 86.4% |
| VAG407314[1] | 1.57E+07 | | | | | |
| Future Growth[2] | 4.40E+08 | | | | | |

[1]Any issued permit will include bacteria effluent limits in accordance with applicable permit guidance and will ensure the discharge meets the applicable numeric water quality criteria for bacteria at the end-of-pipe.
[2]The WLA reflects an allocation for potential future permits issued for bacteria control.

Table E.13. Little Buffalo Creek TMDL (cfu/day) for E. coli.

| Impairment | WLA[1] | LA | MOS | TMDL | Existing Load | Percent Reduction |
|---|---|---|---|---|---|---|
| Little Buffalo Creek (VAC-L76R_LFF01A00) | 8.85E+08 | 1.67E+10 | Implicit | 1.76E+10 | 1.23E+11 | 85.7% |
| VA0062421[1] | 5.40E+08 | | | | | |
| Future Growth[2] | 3.45E+08 | | | | | |

[1]Any issued permit will include bacteria effluent limits in accordance with applicable permit guidance and will ensure the discharge meets the applicable numeric water quality criteria for bacteria at the end-of-pipe.
[2]The WLA reflects an allocation for potential future permits issued for bacteria control.

## Consideration of Critical Condition

The Hyco River, Aarons Creek, Beech Creek, and Little Buffalo Creek flow through a predominantly rural setting. The dominant land uses in the basin are forested (57%) and pasture (18%). Potential sources of *E. coli* include runoff from livestock grazing, manure applications, wildlife deposition, point source dischargers, and residential waste.

The model simulation period was selected to include both low flow and high flow conditions, thus covering all the flow regimes. The continuous simulation from January 1, 2005 through December 31, 2012 used in this TMDL will guarantee that the critical conditions were addressed in the TMDL.

## Consideration of Seasonal Variability

Seasonal variations involve changes in streamflow and water quality because of hydrologic and climatological patterns. Seasonal variations were explicitly included in the modeling approach for this TMDL. The continuous simulation model developed for this TMDL explicitly incorporated the seasonal variations of rainfall, runoff, and fecal coliform wash-off by using an hourly time-step. In addition, fecal coliform accumulation rates for each land use were developed on a monthly basis. This allowed for the consideration of temporal variability in fecal coliform loading within the watershed.

## Reasonable Assurance for Implementation

Several measures will be employed to provide reasonable assurance that the TMDL will be implemented. These include continuing monitoring of bacteria in the impaired segments to determine effectiveness of TMDL implementation; development of implementation plan and schedule in accordance with requirements of the Virginia's 1997 Water Quality Monitoring Information and Restoration Act; coordination with all other planning efforts such as with the implementation planning to address sediment TMDL in Coleman Creek; and active participation of watershed stakeholders not only during the development of the TMDL but also its implementation.

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# 1.0 INTRODUCTION

## 1.1 Regulatory Guidance

Section 303(d) of the Clean Water Act and the Environmental Protection Agency (EPA)'s Water Quality Planning and Management Regulations (40 CFR Part 130) require states to develop Total Maximum Daily Loads (TMDLs) for waterbodies that are exceeding water quality standards. A TMDL represents the total pollutant loading that a waterbody can receive without violating water quality standards. The TMDL process establishes the allowable loadings of pollutants for a waterbody based on the relationship between pollution sources and in-stream water quality conditions. By following the TMDL process, states can establish water quality based controls to reduce pollution from both point and non-point sources to restore and maintain the quality of their water resources (USEPA, 2001).

The lead state regulatory agency for environmental matters in Virginia is the Department of Environmental Quality (VADEQ). VADEQ works in coordination with the Virginia Department of Conservation and Recreation (VADCR), the Department of Mines, Minerals, and Energy (VDMME), and the Virginia Department of Health (VDH) to develop and implement a more effective TMDL program. VADEQ is the lead agency for the development of TMDLs statewide, and focuses its efforts on all aspects of reduction and prevention of pollution to state waters. VADEQ ensures compliance with the Federal Clean Water Act and the Water Quality Planning Regulations, as well as with the Virginia Water Quality Monitoring, Information, and Restoration Act (WQMIRA), passed by the Virginia General Assembly in 1997, and coordinates public participation throughout the TMDL development process.

Within the context of the TMDL program, until recently a primary role of VADCR was to regulate stormwater discharges from construction sites, and from municipal separate storm sewer systems (MS4s) through the Virginia Stormwater Management Program (VSMP). As of July 1, 2013, these two stormwater regulatory programs are administered by VADEQ. VADEQ also manages the important role of initiating non-point source pollution control programs statewide through the use of federal grant money. VDMME focuses its efforts on issuing surface mining permits and National Pollution Discharge Elimination System (NPDES) permits for industrial and mining operations. Lastly, VDH monitors waters for fecal coliform, classifies waters for shellfish growth and harvesting, and conducts surveys to determine sources of bacterial contamination (VADEQ, 2001).

As required by the Clean Water Act and WQMIRA, VADEQ develops and maintains a listing of all impaired waters in the state that details the pollutant(s) causing each impairment and the potential source(s) of each pollutant. This list is referred to as the 303(d) List of Impaired Waters. In addition to 303(d) List development, WQMIRA directs VADEQ to develop and implement TMDLs for listed waters (VADEQ, 2001). Once TMDLs have been developed, they are distributed for public comment and then submitted to the EPA for approval.

## 1.2 Impairment Listing

This report addresses the impaired segments of the Hyco River, Aarons Creek, Beech Creek, and Little Buffalo Creek listed on the 2012 Impaired Waters - 303(d) List for recreation use due to exceedances of the criteria for *E. coli* bacteria. Table 1.1 shows the summary of the impaired segments that are addressed in this report. As shown in Table 1.1, Figures 1.1 and 1.2, the nine impaired stream segments listed are grouped into four separate TMDL watersheds.

*Table 1.1. Summary of Bacterial Impairments.*

| TMDL Watershed | Impaired Segment | 305b Segment ID | Year First Listed |
|---|---|---|---|
| Aarons Creek | Aarons Creek | VAC-L73R_AAR01A00 | 2010 |
| | North Fork Aarons Creek | VAC-L73R_NFA01A06 | 2012 |
| Hyco River | Hyco River | VAC-L74R_HYC02A06 | 2006 |
| | Hyco River | VAC-L74R_HYC01A00 | 2008 |
| | Little Coleman Creek | VAC-L74R_LOL01A06 | 2008 |
| | Coleman Creek | VAC-L74R_CLB01A06 | 2008 |
| | Big Bluewing Creek | VAC-L74R_BLU01A08 | 2008 |
| Beech Creek | Beech Creek | VAC-L75R_BEE01A98 | 2008 |
| Little Buffalo Creek | Little Buffalo Creek | VAC-L76R_LFF01A00 | 2004 |

## 1.3 Applicable Water Quality Standard

Water quality standards consist of designated uses for a waterbody and water quality criteria necessary to support those designated uses. According to Virginia Water Quality Standards (9 VAC 25-260-5), the term ‘water quality standards’ is defined as:

> *“provisions of state or federal law which consist of a designated use or uses for the waters of the Commonwealth and water quality criteria for such waters based upon such uses. Water quality standards are to protect the public health or welfare, enhance the quality of water and serve the purposes of the State Water Control Law (§62.1-44.2 et seq. of the Code of Virginia) and the federal Clean Water Act (33 USC §1251 et seq.).”*

## 1.4 Designated Uses

According to Virginia Water Quality Standards (9 VAC 25-260-10):

> “*…all state waters are designated for the following uses: recreational uses (e.g., swimming and boating); the propagation and growth of a balanced indigenous population of aquatic life, including game fish, which might be reasonably expected to inhabit them; wildlife; and the production of edible and marketable natural resources (e.g., fish and shellfish*).”

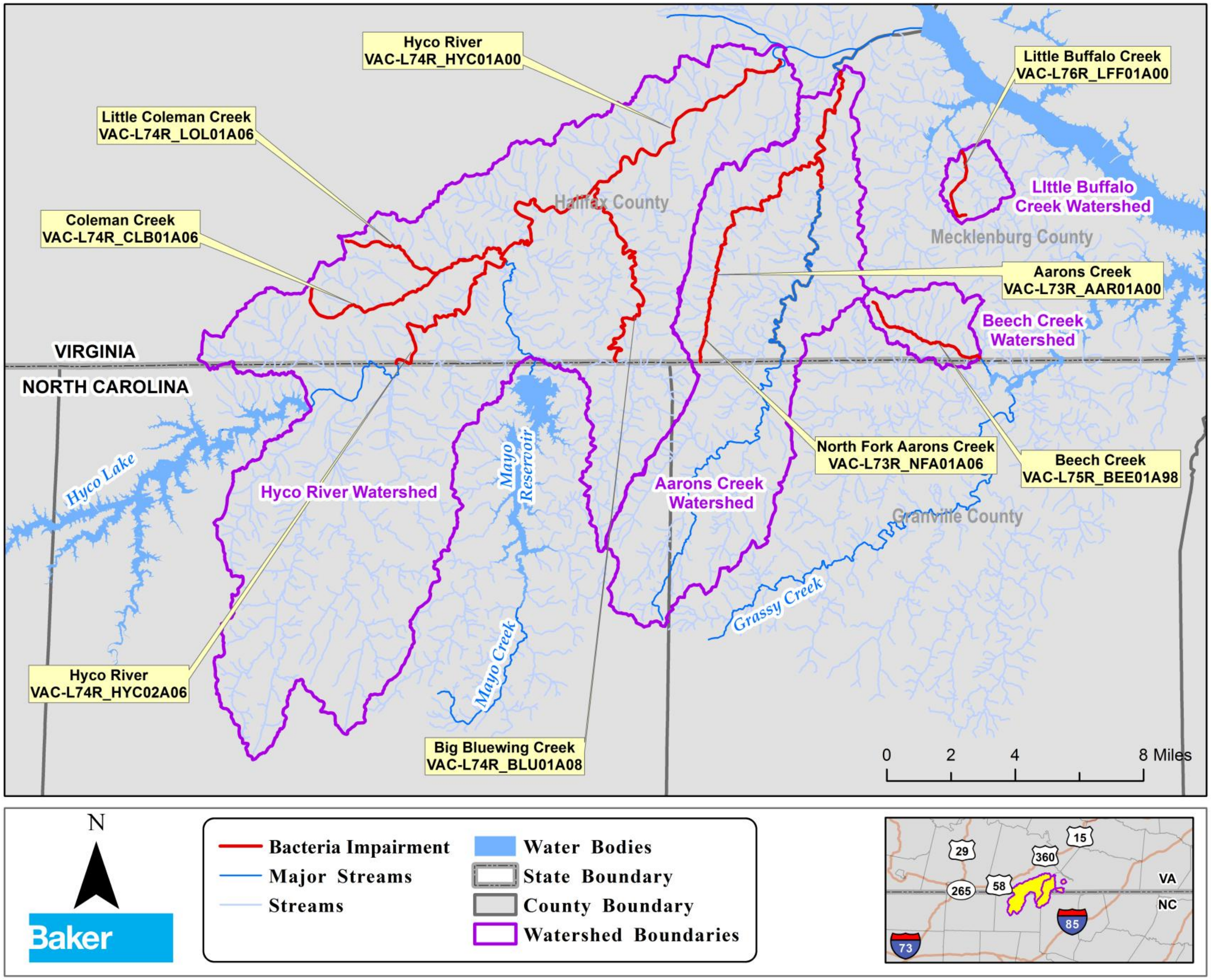


*Figure 1.1. Impaired Segments and Watershed Boundaries for the TMDL watersheds.*

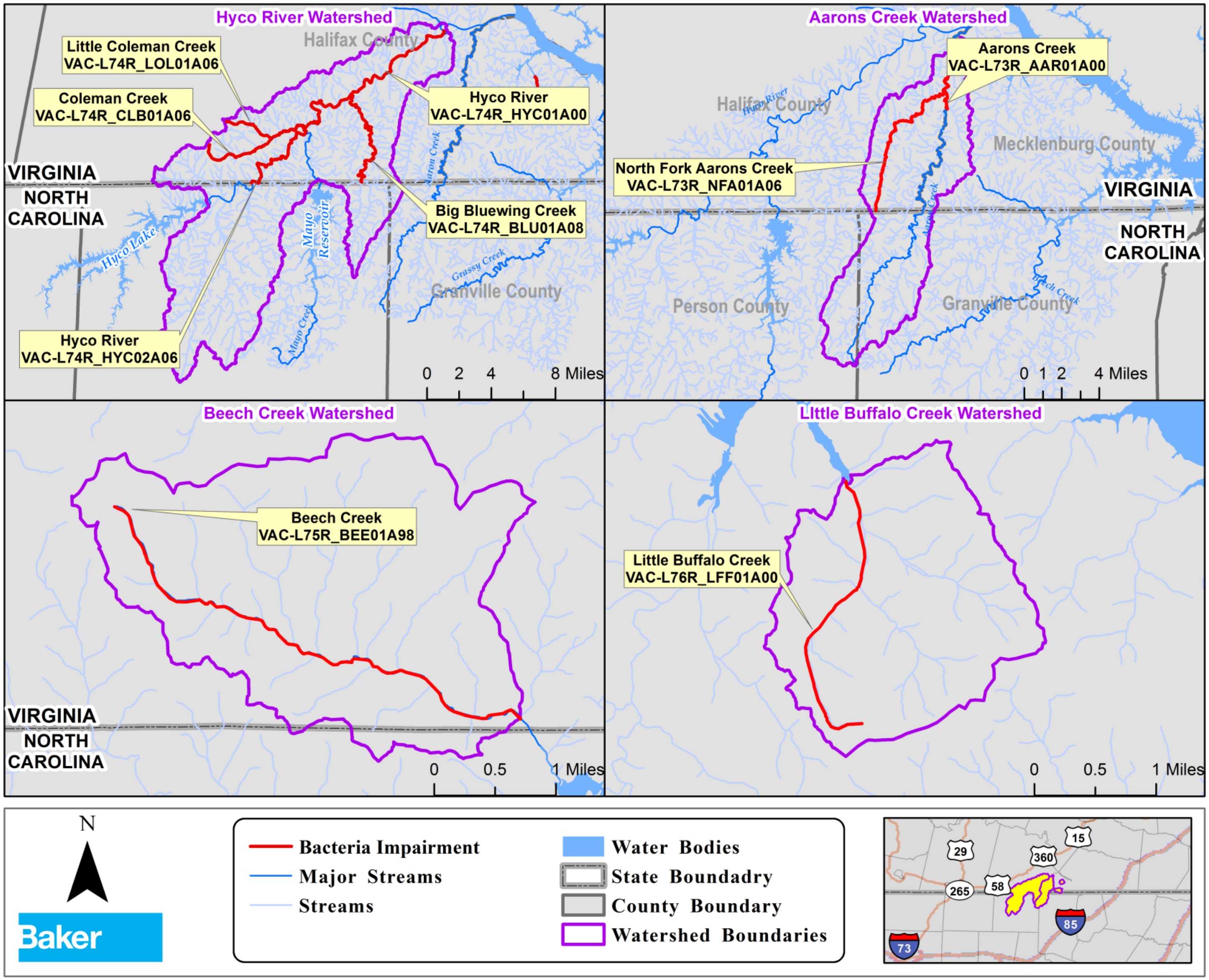


*Figure 1.2. Detailed View of the TMDL Watershed Boundaries.*

### 1.5 Applicable Water Quality Criteria for Bacteria

Effective February 1, 2010, VADEQ specified a new bacteria standard in 9 VAC 25-260-170.A. These standards replaced the existing fecal coliform standard of 9 VAC 25-260-170. For a non-shellfish supporting waterbody to be in compliance with Virginia bacteria standards for primary contact recreation, the current criteria are as follows:

> *"E. coli bacteria shall not exceed a monthly geometric mean of 126 CFU/100 ml in freshwater...Geometric means shall be calculated using all data collected during any calendar month with a minimum of four weekly samples… If there are insufficient data to calculate monthly geometric means in freshwater, no more than 10% of the total samples in the assessment period shall exceed 235 E. coli CFU/100 ml."*

These criteria were adopted because there is a stronger correlation between the concentration of *E. coli* and the incidence of gastrointestinal illness than with fecal coliform. *E. coli* are bacteriological organisms that can be found in the intestinal tract of warm-blooded animals. Like fecal coliform bacteria, these organisms indicate the presence of fecal contamination.

### 1.6 Selection of TMDL Endpoint and Water Quality Targets

One of the first steps in TMDL development is to determine a numeric endpoint, or water quality target, for each impaired segment. A water quality target compares the current stream conditions to the expected restored stream conditions after TMDL load reductions are implemented. Numeric endpoints for the bacteria impaired segments of the Hyco River, Aarons Creek, Beech Creek, and Little Buffalo Creek are established in the Virginia Water Quality Standards (9 VAC 25-260). These standards state that all waters in Virginia should be free from any substances that can cause the water to exceed the state numeric criteria, interfere with its designated uses, or adversely affect human health and aquatic life. The current water quality target for freshwater, non-shellfish waters; are given in *Virginia Water Quality Standards for Bacteria* section 170 (SWCB, 2011).

# 2.0 WATERSHED CHARACTERIZATION

### 2.1 Watershed Boundaries

Located between Richmond, Virginia and Raleigh, North Carolina, the study area in this report spans through Halifax County and Mecklenburg County in Virginia, as well as Person County and Granville County in North Carolina (Figure 1.1).The boundary area lies primarily south of U.S. Route 360/ Philpott Road and U.S. 58/Bill Tuck Highway and north of US Route 158 (Oxford Road). For modeling purposes, the nine impaired stream segments listed in Table 1.1 are grouped into four separate watersheds as shown in Figures 1.1 and 1.2. These watersheds are delineated to include the drainage areas of the impaired segments and their tributaries. When available, locations of flow monitoring stations were used to define the upstream boundaries of the watersheds. For example, drainage areas corresponding to the Hyco Lake and the Mayo Reservoir are not included and instead will be represented as boundary conditions during modeling. The four watersheds that contain the nine impaired stream segments are the following:

1. The Hyco River watershed is approximately 107,239 acres and covers portions of Person County, North Carolina, Granville County, North Carolina, and Halifax County, Virginia. The impaired water segments located in the Hyco River watershed include: Big Bluewing Creek (VAC-L74R_BLU01A08), Coleman Creek (VAC-L74R_CLB01A06), Little Coleman Creek (VAC-L74R_LOL01A06), and Hyco River (VAC-L74R_HYC01A00 and VAC-L74R_HYC02A06).

2. The Aarons Creek watershed encompasses portions of Halifax County and Mecklenburg County in Virginia and a small portion of Granville County, North Carolina. It is approximately 42,473 acres. Aarons Creek (VAC-L73R_AAR01A00) and North Fork Aarons Creek (VAC-L73R_NFA01A06) discharge into Aarons Creek watershed.

3. The Little Buffalo Creek watershed contains Little Buffalo Creek (VAC-L76R_LFF01A00). It is located completely within Mecklenburg County, Virginia and is approximately 2,385 acres.

4. The Beech Creek watershed which contains Beech Creek (VAC-L75R_BEE01A98) is primarily located in Mecklenburg County, Virginia and a small portion of Granville County, Virginia. It covers approximately 4,219 acres.

Table 2.1 shows the percent area of each county within each of the four watersheds.

*Table 2.1. Percent of County Area within Each Watershed.*

| Watershed | County | Total County Area (acres) | Area of Watershed (acres) | Percent of County |
|---|---|---|---|---|
| Hyco River | Halifax County, VA | 531,019 | 58,297 | 10.98 |
| | Person County, NC | 258,758 | 51,014 | 19.71 |
| | Granville County, NC | 343,590 | 695 | 0.20 |
| Aarons Creek | Halifax County, VA | 531,019 | 15,588 | 2.94 |
| | Mecklenburg County, VA | 434,814 | 7,388 | 1.70 |
| | Granville County, NC | 343,590 | 1,484 | 0.43 |
| Beech Creek | Mecklenburg County, VA | 434,814 | 4,091 | 0.94 |
| | Granville County, NC | 343,590 | 128 | 0.04 |
| Little Buffalo Creek | Mecklenburg County, VA | 434,814 | 2,385 | 0.55 |

## 2.2 Topography

Topography and relief data were obtained from the United States Geological Survey (USGS) National Data Set at a resolution of 1/3 arc-second (approximately 10 meters). The region is characterized with low, rolling hills ranging in elevation from 320 feet to 500 feet above sea level.

## 2.3 Soils

The characteristics of soils in a watershed play an important role in the amount of generated runoff and erosion that occurs. The soils data were obtained from the United States Department of Agriculture's Natural Resources Conservation Service (USDA, 2013a) Soil Survey Geographic Database (SSURGO). Table 2.2 is a complete list of soil types found within each watershed (USDA, 2013b).

The Hyco River watershed comprises of a wide variety of soils including: Appling, Georgeville, Goldston-Montonia, Siloam, Spriggs-Rasalo, and Wedowee. The Aarons Creek watershed is composed of: Cid, Cid-Lignum, Herndon, Orange, Tarrus-Badin, and Virgilina. These soils can be characterized as very deep, well drained, and moderately permeable. The Beech Creek watershed is mostly of the Herndon soil series, which is well-drained, generates medium runoff and has moderate permeability. Lastly, Little Buffalo Creek watershed has a high percentage of Appling. Appling is a well-drained soil with medium to rapid runoff and moderate permeability.

*Table 2.2. Distribution of Soils in Each Watershed.*

| Soil Name | Acres | Percent of Watershed |
|---|---|---|
| **Hyco River Watershed Soils** | | |
| Spriggs-Rasalo | 8,298 | 8 |
| Wedowee | 7,859 | 7 |
| Siloam | 7,664 | 7 |

| Soil Name | Acres | Percent of Watershed |
|---|---|---|
| Georgeville | 6,344 | 6 |
| Appling | 5,372 | 5 |
| Goldston-Montonia | 5,268 | 5 |
| Clifford | 5,197 | 5 |
| Codorus and Hatboro | 4,725 | 4 |
| Montonia-Goldston | 3,743 | 4 |
| Rasalo-Orange | 3,488 | 3 |
| Chewacla | 3,317 | <1 |
| Tarrus-Badin | 3,282 | 3 |
| Cid | 3,024 | 3 |
| Nanford-Badin | 2,842 | 3 |
| Tarrus | 2,824 | 3 |
| Rasalo | 2,726 | 2 |
| Herndon | 2,719 | 2 |
| Virgilina | 2,694 | 3 |
| Cid-Lignum | 2,612 | 3 |
| Virgilina-Poindexter | 2,530 | 3 |
| Halifax | 2,361 | 2 |
| Lignum | 2,317 | 2 |
| Goldston | 1,362 | 1 |
| Oak Level | 1,248 | 1 |
| Montonia-Nanford | 1,193 | 1 |
| Water | 1,122 | 1 |
| Iredell | 982 | <1 |
| Cecil | 844 | <1 |
| Fairview | 808 | <1 |
| Minnieville | 807 | <1 |
| Chewacla and Wehadkee | 772 | 3 |
| Toast | 655 | <1 |
| Nathalie | 496 | <1 |
| Udorthents | 479 | <1 |
| Enon | 464 | <1 |
| Jackland-Orange | 433 | <1 |
| Urban land | 400 | <1 |
| Orange | 385 | <1 |
| Dogue | 384 | <1 |
| Poindexter | 381 | <1 |
| Rion | 323 | <1 |
| Helena-Sedgefield | 304 | <1 |
| Vance | 267 | <1 |
| Nason | 265 | <1 |

| Soil Name | Acres | Percent of Watershed |
|---|---|---|
| Rhodhiss | 264 | <1 |
| Riverview | 216 | <1 |
| Spriggs | 199 | <1 |
| Banister-Kinkora | 174 | <1 |
| Casville | 114 | <1 |
| Turbeville | 107 | <1 |
| Danripple | 103 | <1 |
| Helena | 96 | <1 |
| Yadkin | 85 | <1 |
| McQueen | 75 | <1 |
| Appomattox | 73 | <1 |
| Wickham | 42 | <1 |
| Tatum | 34 | <1 |
| Dan River (water) | 21 | <1 |
| Mecklenburg | 20 | <1 |
| Dam | 16 | <1 |
| Comus | 9 | <1 |
| Toccoa | 7 | <1 |
| Bentley | 4 | <1 |
| Wilkes | 1 | <1 |
| **Total** | **107,239** | **100** |
| **Aarons Creek Watershed Soils** | | |
| Georgeville | 6,380 | 15 |
| Cid | 4,888 | 12 |
| Enon | 4,378 | 10 |
| Virgilina | 4,185 | 10 |
| Herndon | 3,655 | 9 |
| Orange | 2,191 | 5 |
| Badin | 2,030 | 5 |
| Tarrus | 2,018 | 5 |
| Goldston | 1,715 | 4 |
| Lignum | 1,663 | 4 |
| Roanoke | 1,546 | 4 |
| Montonia | 1,459 | 3 |
| Congaree | 1,326 | 3 |
| Worsham | 1,084 | 3 |
| Tatum | 985 | 2 |
| Nanford | 538 | 1 |
| Nason | 491 | 1 |
| Wynott | 386 | 1 |

| Soil Name | Acres | Percent of Watershed |
|---|---|---|
| Chewacla | 299 | 1 |
| Water | 241 | 1 |
| Riverview | 204 | <1 |
| Wehadkee | 184 | <1 |
| Armenia | 171 | <1 |
| State | 118 | <1 |
| Appomattox | 81 | <1 |
| Spriggs | 41 | <1 |
| Pacolet | 28 | <1 |
| Mattaponi | 26 | <1 |
| Masada | 24 | <1 |
| Turbeville | 19 | <1 |
| Altavista | 17 | <1 |
| Minnieville | 15 | <1 |
| Wedowee | 15 | <1 |
| Sedgefield | 13 | <1 |
| Enott | 11 | <1 |
| Poindexter | 11 | <1 |
| Appling | 10 | <1 |
| Udorthents | 7 | <1 |
| Oak Level | 6 | <1 |
| Abell | 5 | <1 |
| Cullen | 5 | <1 |
| Toccoa | 5 | <1 |
| **Total** | **42,473** | **100** |
| **Beech Creek Watershed Soils** | | |
| Herndon | 2,300 | 55 |
| Orange | 654 | 16 |
| Georgeville | 306 | 7 |
| Wehadkee | 253 | 6 |
| Worsham | 234 | 6 |
| Appling | 204 | 5 |
| Nason | 63 | 1 |
| Tatum | 54 | 1 |
| Masada | 22 | <1 |
| Enott | 19 | <1 |
| Chewacla | 18 | <1 |
| Goldston | 15 | <1 |
| Wedowee | 15 | <1 |
| Water | 14 | <1 |

| Soil Name | Acres | Percent of Watershed |
|---|---|---|
| Congaree-Chewacla | 12 | <1 |
| Altavista | 9 | <1 |
| Helena | 6 | <1 |
| Enon | 5 | <1 |
| Helena-Worsham | 5 | <1 |
| Abell | 3 | <1 |
| Gullied land | 3 | <1 |
| Louisburg | 3 | <1 |
| Chewacla and Wehadkee | 2 | <1 |
| Iredell | 0 | <1 |
| **Total** | **4,219** | **100** |
| **Little Buffalo Creek Watershed Soils** | | |
| Appling | 1,749 | 73 |
| Wedowee | 275 | 12 |
| Congaree-Chewacla | 135 | 6 |
| Louisburg | 78 | 3 |
| Wehadkee | 53 | 2 |
| Worsham | 38 | 2 |
| Water | 24 | 1 |
| Helena | 19 | <1 |
| Abell | 12 | <1 |
| Cecil | 3 | <1 |
| Gullied land | 1 | <1 |
| Helena-Worsham | 1 | <1 |
| **Total** | **2,388** | **100** |

Given the number and diversity of soils in the different watersheds, it is helpful to characterize them by hydrologic rating. The hydrologic soil group classification is a means of grouping soils by similar infiltration and runoff characteristics during periods of prolonged precipitation. The four categories are based on physical drainage properties, such as texture and permeability, as well as some physiographic properties, such as depth to the bedrock and water table; these categories are defined in Table 2.3. All four watersheds have a high percentage of B soils. In particular, Beech Creek and Little Buffalo Creek watersheds are composed of 70% and 94%, respectively, of B soils. B soils are sandy loam soils with moderately fine to moderately coarse textures. They have a moderate infiltration rate when throroughly wet. Hyco River watershed and Aarons Creek watershed also have high amounts of group C soils. Soils in group C are typically silty-loam sands with an impending layer, and have a slow infiltration rate when thoroughly wetted. Group D soils are also prominent with the low-lying areas of the Hyco River watershed, Aarons Creek watershed, and Beech Creek watershed. Group D soils include clay soils with a high runoff potential and a very slow infiltration rate when thoroughly wetted. The distribution of the hydrologic soil groups is summarized in Table 2.4 and illustrated in Figures 2.1 through 2.4.

*Table 2.3. Hydrologic Soil Group Classification.*

| Hydrologic Soil Group | Description |
|---|---|
| A | High infiltration rates. Soils are deep, well drained to excessively drained sand and gravels. |
| B | Moderate infiltration rates. Deep and moderately deep, moderately to well drained soils with moderately coarse textures. |
| C | Moderate to slow infiltration rates. Soils with layers impeding downward movement of water or soils with moderately fine or fine textures. |
| D | Very slow infiltration rates. Soils are clayey, have high water table, or shallow to an impervious cover. |
| B/D | Combination of Hydrologic Soil Groups B and D. |
| C/D | Combination of Hydrologic Soil Groups C and D. |

*Table 2.4. Distribution of Hydrologic Soil Groups in Each Watershed.*

| | Watersheds | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Hyco River | | Aarons Creek | | Beech Creek | | Little Buffalo Creek | |
| Hydrologic Soil Group | Area (acres) | % area | Area (acres) | % area | Area (acres) | % area | Area (acres) | % area |
| A | 957 | <1 | 5 | 0 | - | - | - | - |
| B | 41,633 | 39 | 14,668 | 35 | 2,958 | 70 | 2,252 | 94 |
| B/D | 4,691 | 4 | 483 | 1 | 2 | <1 | - | - |
| C | 43,585 | 41 | 9,227 | 22 | 101 | 2 | 20 | <1 |
| C/D | 982 | <1 | 1,733 | 4 | - | <1 | - | - |
| D | 13,855 | 13 | 16,111 | 38 | 1,141 | 27 | 91 | 4 |
| Unknown | 1,537 | 2 | 248 | 1 | 16 | <1 | 25 | 1 |
| **Total*** | 107,239 | 100 | 42,473 | 100 | 4,219 | 100 | 2,388 | 100 |
| *minor discrepancies in total areas from other tables are due to round-off errors. | | | | | | | | |

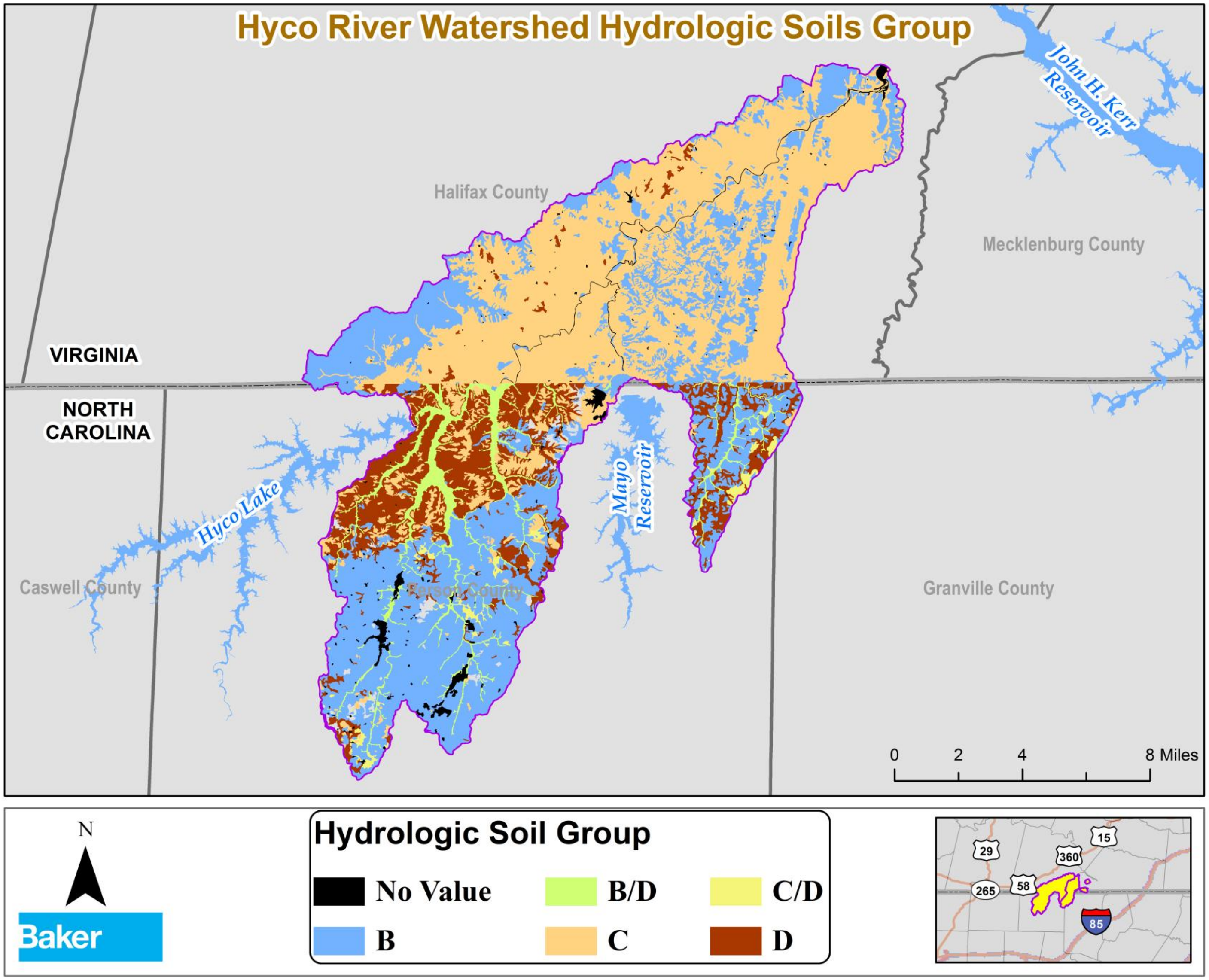


*Figure 2.1. Hydrologic Soil Group Distribution within Hyco River Watershed.*


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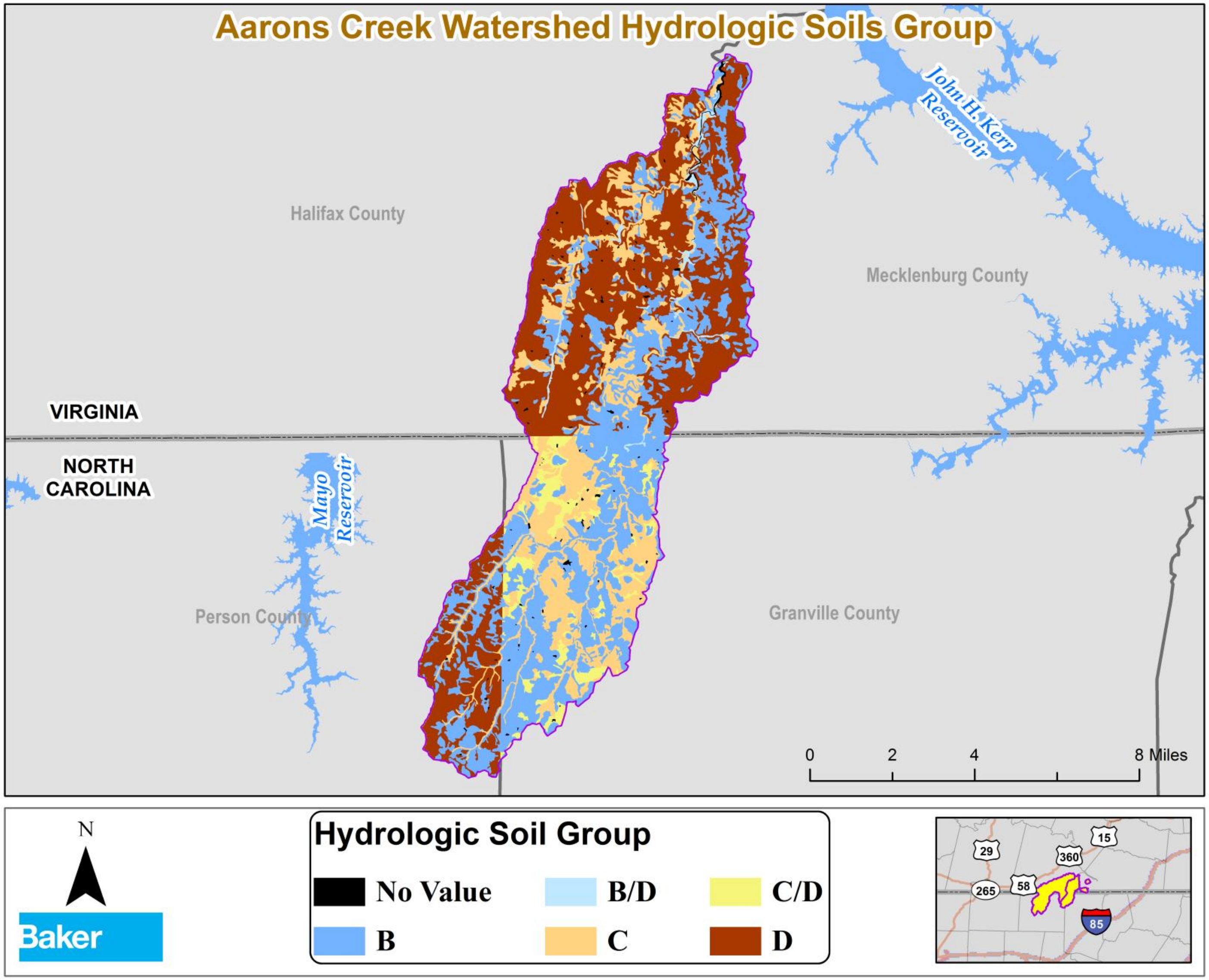


*Figure 2.2. Hydrologic Soil Group Distribution within Aarons Creek Watershed.*

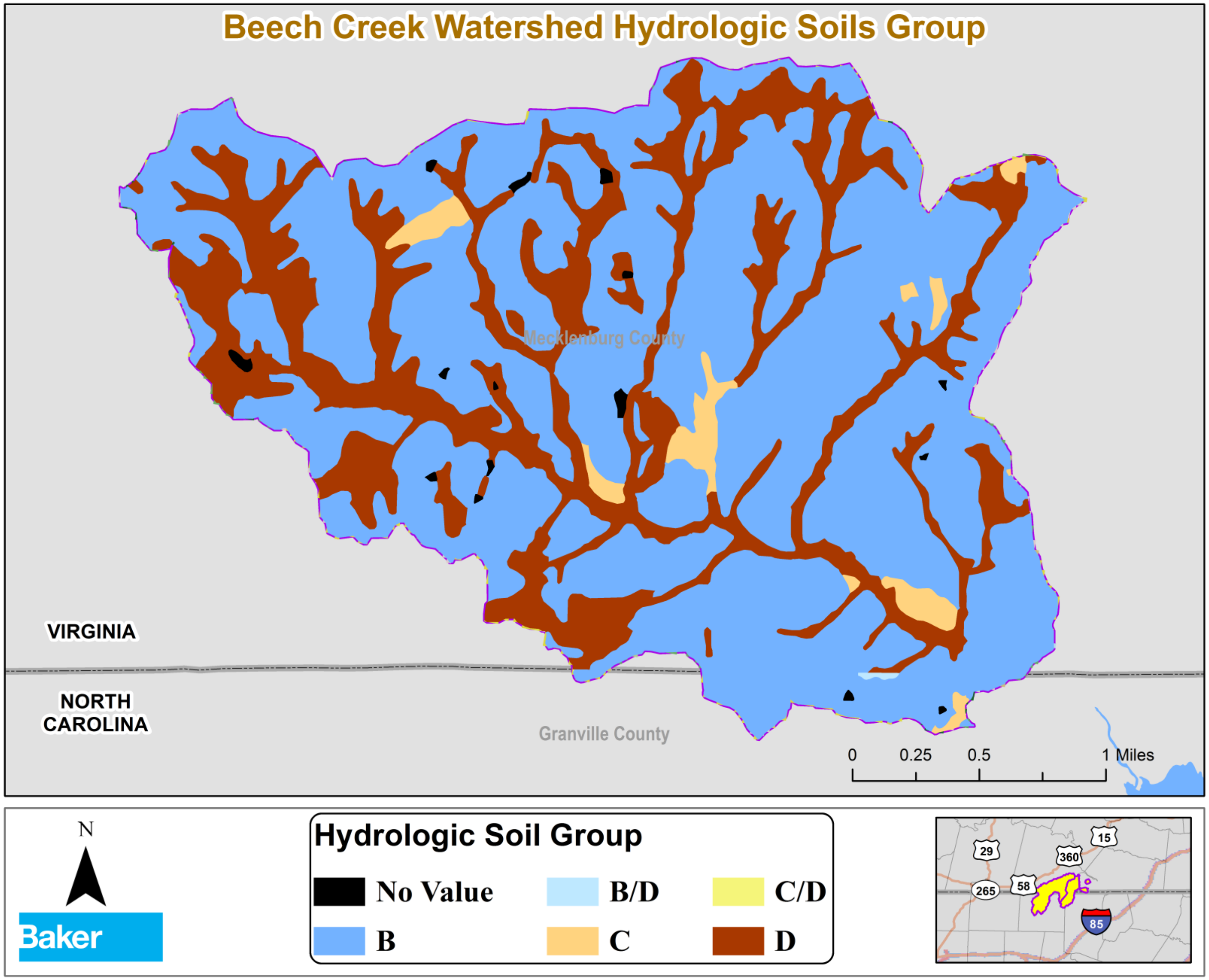


*Figure 2.3. Hydrologic Soil Group Distribution within Beech Creek Watershed.*

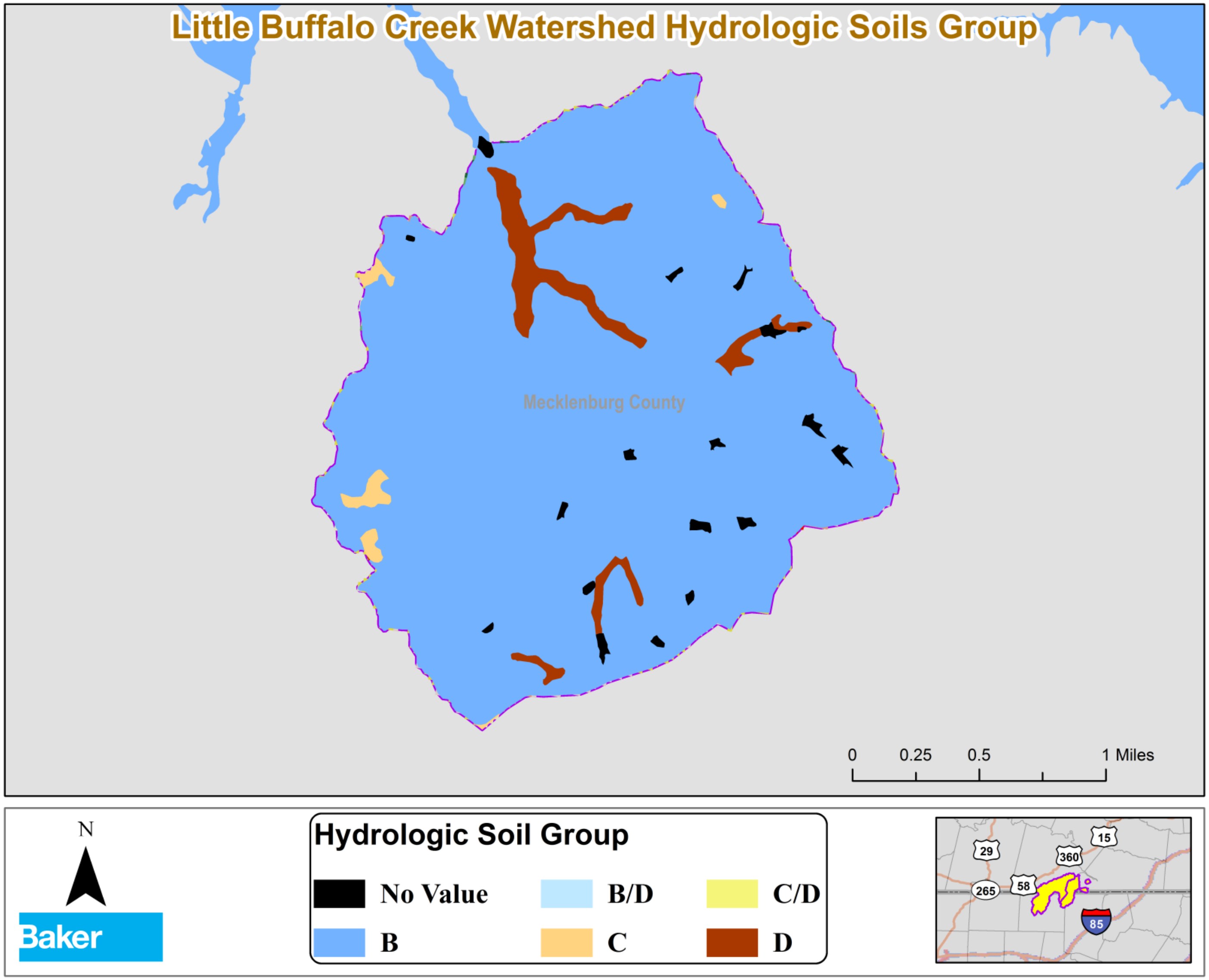


*Figure 2.4. Hydrologic Soil Group Distribution within Little Buffalo Creek Watershed.*

## 2.4 Land Use

Land cover/land use information was obtained from the 2006 National Land Cover Database (MRLC, 2013). Figures 2.5 through 2.8 show the distribution of the land use, while Table 2.5 summarizes the land use by each category. The Hyco River watershed, Aarons Creek watershed, and Beech Creek watershed consist primarily of forested lands and some pasture lands. Little Buffalo Creek watershed is equally comprised of pasture and forested lands. Table 2.6 describes the land use classification scheme. The 2012 National Agricultural Statistics Service (NASS) Crop Data Layer was used to distinguish pasture from hay.

*Table 2.5. Land Use Distribution within Watersheds.*

| NLCD Land Use Types | Acres | Percent of Watershed's Land Use Area |
|---|---|---|
| **Hyco River Watershed Land Use Types** | | |
| Open Water | 679 | <1 |
| Developed, Open Space | 4,403 | 4 |
| Developed, Low Intensity | 1,204 | 1 |
| Developed, Medium Intensity | 390 | <1 |
| Developed, High Intensity | 193 | <1 |
| Barren Land (Rock/Sand/Clay) | 580 | <1 |
| Deciduous Forest | 45,131 | 42 |
| Evergreen Forest | 17,164 | 16 |
| Mixed Forest | 6,367 | 6 |
| Shrub/Scrub | 2,593 | 2 |
| Cultivated Crops | 604 | <1 |
| Woody Wetlands | 4,209 | 4 |
| Emergent Herbaceous Wetlands | 22 | <1 |
| Pasture | 14,626 | 14 |
| Hay | 9,273 | 9 |
| **Total*** | **107,438** | **100** |
| **Aarons Creek Watershed Land Use Types** | | |
| Open Water | 95 | <1 |
| Developed, Open Space | 1,640 | 4 |
| Developed, Low Intensity | 87 | <1 |
| Developed, Medium Intensity | 10 | <1 |
| Developed, High Intensity | 0 | <1 |
| Barren Land (Rock/Sand/Clay) | 100 | <1 |
| Deciduous Forest | 18,832 | 44 |
| Evergreen Forest | 4,914 | 12 |
| Mixed Forest | 2,268 | 5 |
| Shrub/Scrub | 1,385 | 3 |
| Cultivated Crops | 434 | 1 |
| Woody Wetlands | 493 | 1 |

| NLCD Land Use Types | Acres | Percent of Watershed's Land Use Area |
|---|---|---|
| Emergent Herbaceous Wetlands | 2 | <1 |
| Pasture | 7,659 | 18 |
| Hay | 4,517 | 11 |
| **Total*** | **42,437** | **100** |
| **Beech Creek Watershed Land Use Types** | | |
| Open Water | 9 | <1 |
| Developed, Open Space | 118 | 3 |
| Developed, Low Intensity | 1 | <1 |
| Barren Land (Rock/Sand/Clay) | 18 | <1 |
| Deciduous Forest | 1,721 | 41 |
| Evergreen Forest | 430 | 10 |
| Mixed Forest | 198 | 5 |
| Shrub/Scrub | 118 | 3 |
| Cultivated Crops | 63 | 2 |
| Woody Wetlands | 63 | 1 |
| Pasture | 1,121 | 27 |
| Hay | 346 | 8 |
| **Total*** | **4,206** | **100** |
| **Little Buffalo Creek Watershed Land Use Types** | | |
| Open Water | 8 | <1 |
| Developed, Open Space | 165 | 7 |
| Developed, Low Intensity | 58 | 2 |
| Developed, Medium Intensity | 8 | <1 |
| Barren Land (Rock/Sand/Clay) | 66 | 3 |
| Deciduous Forest | 502 | 21 |
| Evergreen Forest | 167 | 7 |
| Mixed Forest | 85 | 4 |
| Shrub/Scrub | 23 | 1 |
| Cultivated Crops | 29 | 1 |
| Woody Wetlands | 104 | 4 |
| Pasture | 719 | 30 |
| Hay | 475 | 20 |
| **Total*** | **2,408** | **100** |
| *minor discrepancies in total areas from other tables are due to round-off errors. | | |

*Table 2.6. Land Use Descriptions.*

| Land use Name | Description |
|---|---|
| Open Water | Areas of open water, generally with less than 25% cover of vegetation or soil. |
| Developed, Open Space | Areas with a mixture of some constructed materials, but mostly vegetation in the form of lawn grasses. Impervious surfaces account for less than 20% of total cover. These areas most commonly include large lot single family housing units, parks, golf courses, and vegetation planted in developed settings for recreation, erosion control, or aesthetic purposes. |
| Developed, Low Intensity | Areas with a mixture of constructed materials and vegetation. Impervious surfaces account for 20% to 49% percent of total cover. These areas most commonly include single family housing units. |
| Developed, Medium Intensity | Areas with a mixture of constructed materials and vegetation. Impervious surfaces account for 50% to 79% of the total cover. These areas most commonly include single family housing units. |
| Developed High Intensity | Highly developed areas where people reside or work in high numbers. Examples include apartment complexes, row houses and commercial/industrial. Impervious surfaces account for 80% to 100% of the total cover. |
| Barren Land (Rock/Sand/Clay) | Areas of bedrock, desert pavement, scarps, talus, slides, volcanic material, glacial debris, sand dunes, strip mines, gravel pits and other accumulations of earthen material. Generally, vegetation accounts for less than 15% of total cover. |
| Deciduous Forest | Areas dominated by trees generally greater than 5 meters tall, and greater than 20% of total vegetation cover. More than 75% of the tree species shed foliage simultaneously in response to seasonal change. |
| Evergreen Forest | Areas dominated by trees generally greater than 5 meters tall, and greater than 20% of total vegetation cover. More than 75% of the tree species maintain their leaves all year. Canopy is never without green foliage. |
| Mixed Forest | Areas dominated by trees generally greater than 5 meters tall, and greater than 20% of total vegetation cover. Neither deciduous nor evergreen species are greater than 75% of total tree cover. |
| Shrub/Scrub | Areas dominated by shrubs; less than 5 meters tall with shrub canopy typically greater than 20% of total vegetation. This class includes true shrubs, young trees in an early successional stage or trees stunted from environmental conditions. |
| Grassland/Herbaceous | Areas dominated by gramanoid or herbaceous vegetation, generally greater than 80% of total vegetation. These areas are not subject to intensive management such as tilling, but can be utilized for grazing. |
| Pasture/Hay – | Areas of grasses, legumes, or grass legume mixtures planted for livestock grazing or the production of seed or hay crops, typically on a perennial cycle. Pasture/hay vegetation accounts for greater than 20% of total vegetation. |
| Cultivated Crops | Areas used for the production of annual crops, such as corn, soybeans, vegetables, tobacco, and cotton, and also perennial woody crops such as orchards and vineyards. Crop vegetation accounts for greater than 20% of total vegetation. This class also includes all land being actively tilled. |
| Woody Wetlands | Areas where forest or shrub land vegetation accounts for greater than 20% of vegetative cover and the soil or substrate is periodically saturated with or covered with water. |
| Emergent Herbaceous Wetlands. | Areas where perennial herbaceous vegetation accounts for greater than 80% of vegetative cover and the soil or substrate is periodically saturated with or covered with water. |

Source: Multi-Resolution Land Characteristics Consortium NLCD (2006)

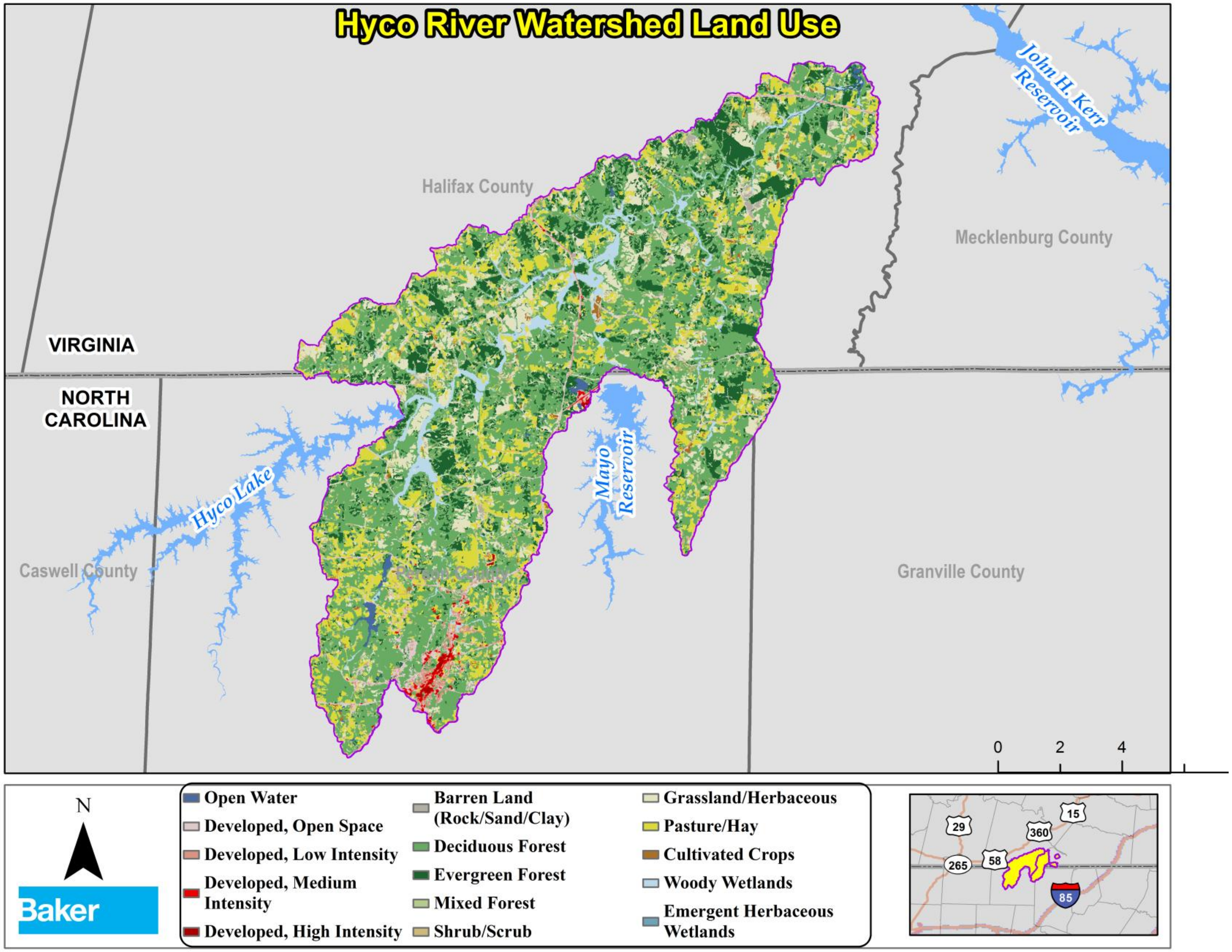


*Figure 2.5. Land Use Distribution within Hyco River Watershed.*

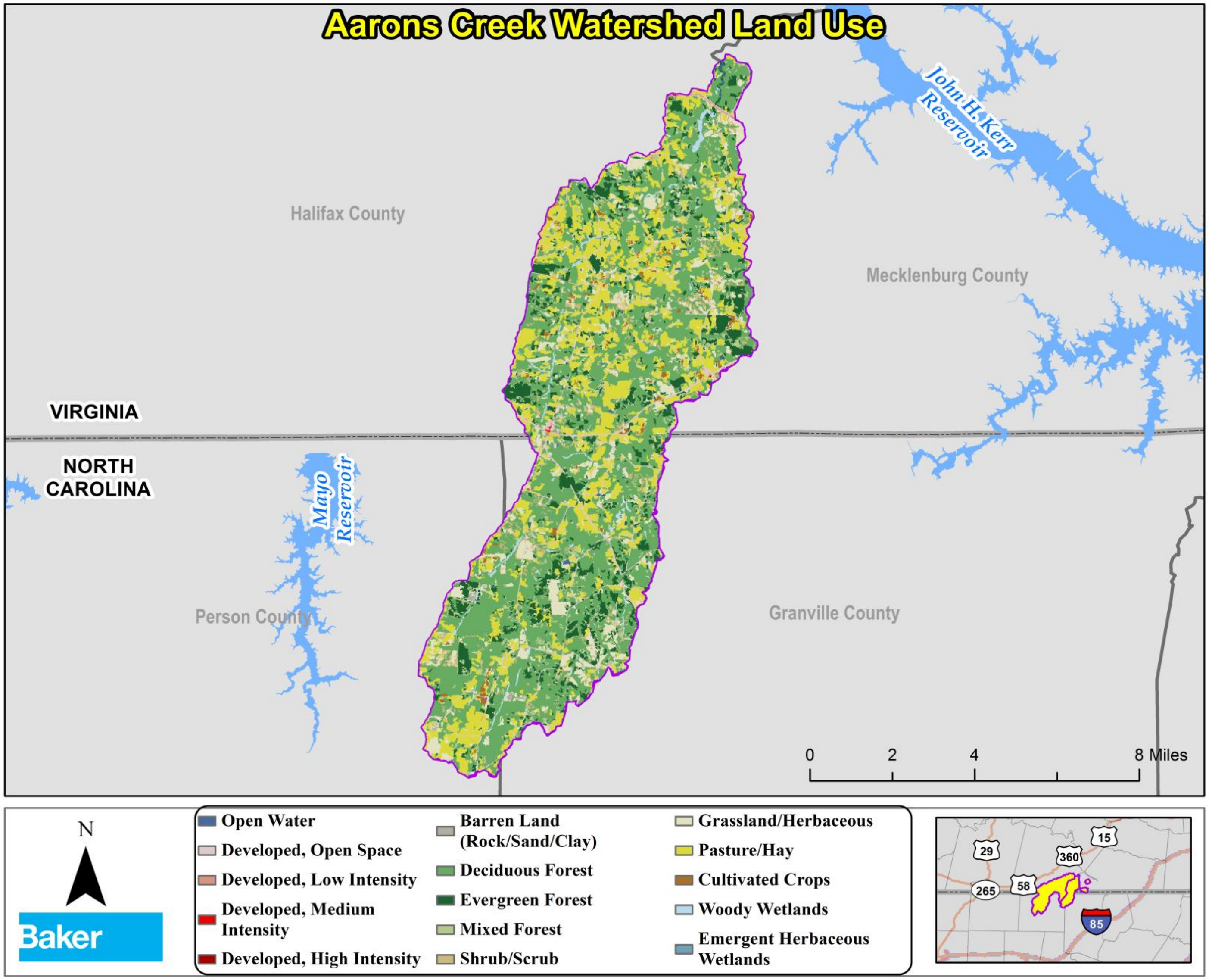


*Figure 2.6. Land Use Distribution within Aarons Creek Watershed.*

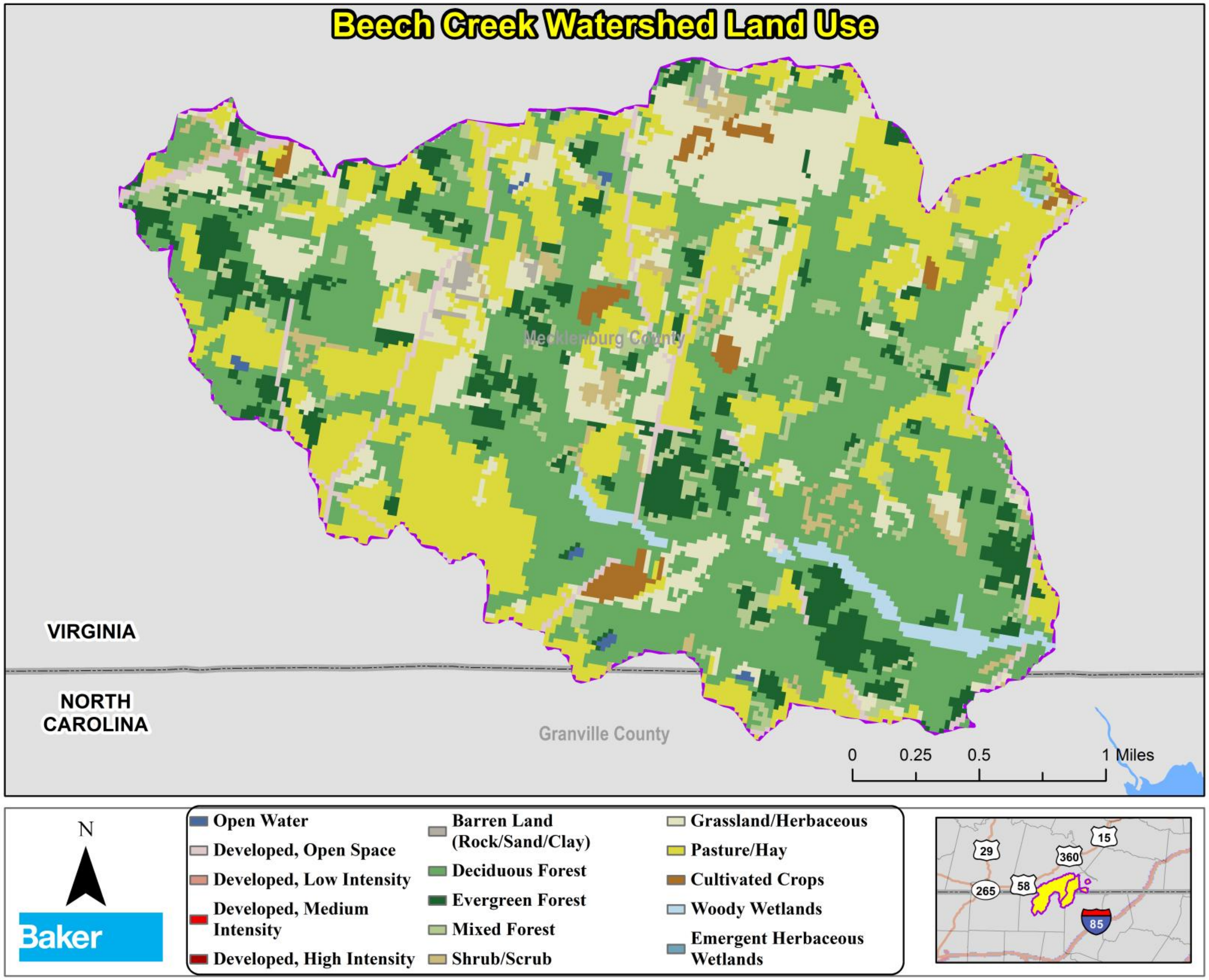


*Figure 2.7. Land Use Distribution within Beech Creek Watershed.*

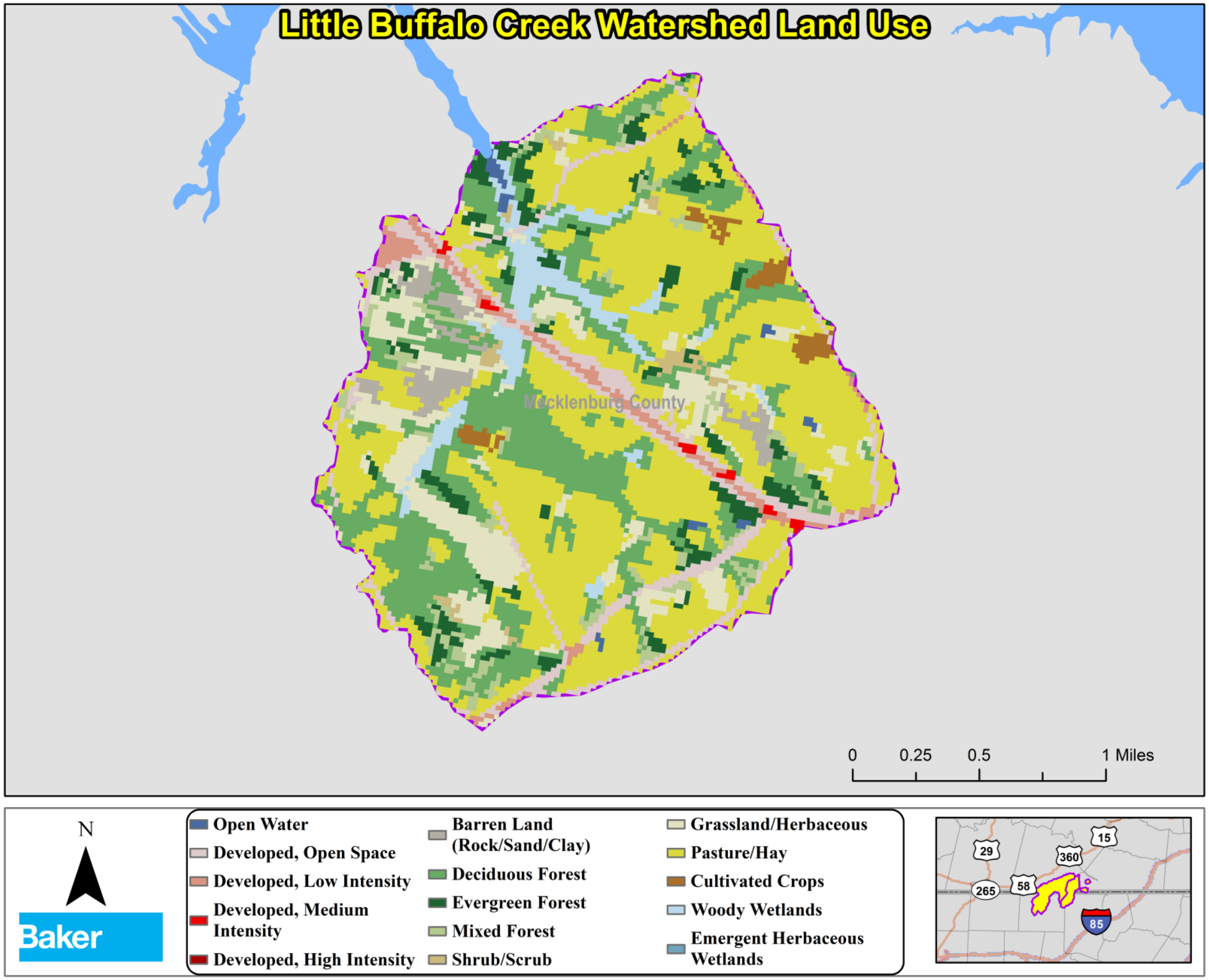


*Figure 2.8. Land Use Distribution within Little Buffalo Creek Watershed.*

## 2.5 Streamflow Data

The U.S Geological Survey (USGS) Virginia and North Carolina water resources information databases list three stream flow gaging stations with flow data in the study area, as shown in Figure 2.9 and Table 2.7. These stations allow for a general understanding of daily, seasonal, and long-term stream flow characteristics. Two stations are located along the Hyco River; one each in Virginia and North Carolina. The third station is located near Bethel Hill, North Carolina, along the Mayo Creek. Since the stations are all located within the Hyco River watershed and none within the other three watersheds, a paired watershed approach will be used to characterize the streamflow in the other watersheds. Aarons Creek watershed and Little Buffalo Creek watershed are located in the same Lower Dan River watershed (HUC 03010104) as Hyco River watershed. Beech Creek is located in the adjacent Middle Roanoke watershed (HUC 03010102). Since both the Lower Dan River watershed and the Middle Roanoke watershed are part of the Southern Piedmont hydrologic region, as defined by the USGS for estimating flood magnitude and frequency for the National Flood Frequency Program, data from the Hyco River watershed can be applied to the other watershed in the same hydrologic region. The flow duration curve in Figure 2.10 describes the percentage of time specified flow discharge are equaled or surpassed during the 1990-2010 time period. A flow duration analysis looks at the cumulative frequency of historic data over a specified period. This analysis results in a curve that relates flow values to the percent of time those values have been equaled or surpassed. Low flows are surpassed a majority of the time, whereas high flows are surpassed infrequently.

*Table 2.7. Information of Selected USGS Stream Flow Gauging Stations.*

| Station | Name | Drainage area ($mi^2$) | Elevation (feet, NGVD29) | Begin Date | End Date | Count | Average Flow* (cfs) | 90th Percentile (cfs) | Median Flow (cfs) |
|---|---|---|---|---|---|---|---|---|---|
| 02077500 | Hyco River Near Denniston, VA | 288 | 315.24 | 7/1/1929 | 11/11/2013 | 24,426 | 258 | 639 | 57 |
| 02077303 | Hyco River Below Abay Drive Near McGehees Mill, NC | 202 | 342.98 | 10/1/1973 | 11/11/2013 | 21,070 | 140.7 | 310 | 20 |
| 02077670 | Mayo Creek Near Bethel Hill, NC | 53.5 | 338.84 | 7/29/1977 | 11/11/2013 | 18,945 | 38.4 | 100 | 7.9 |

* During the period between January 1, 1990 to December 31, 2010

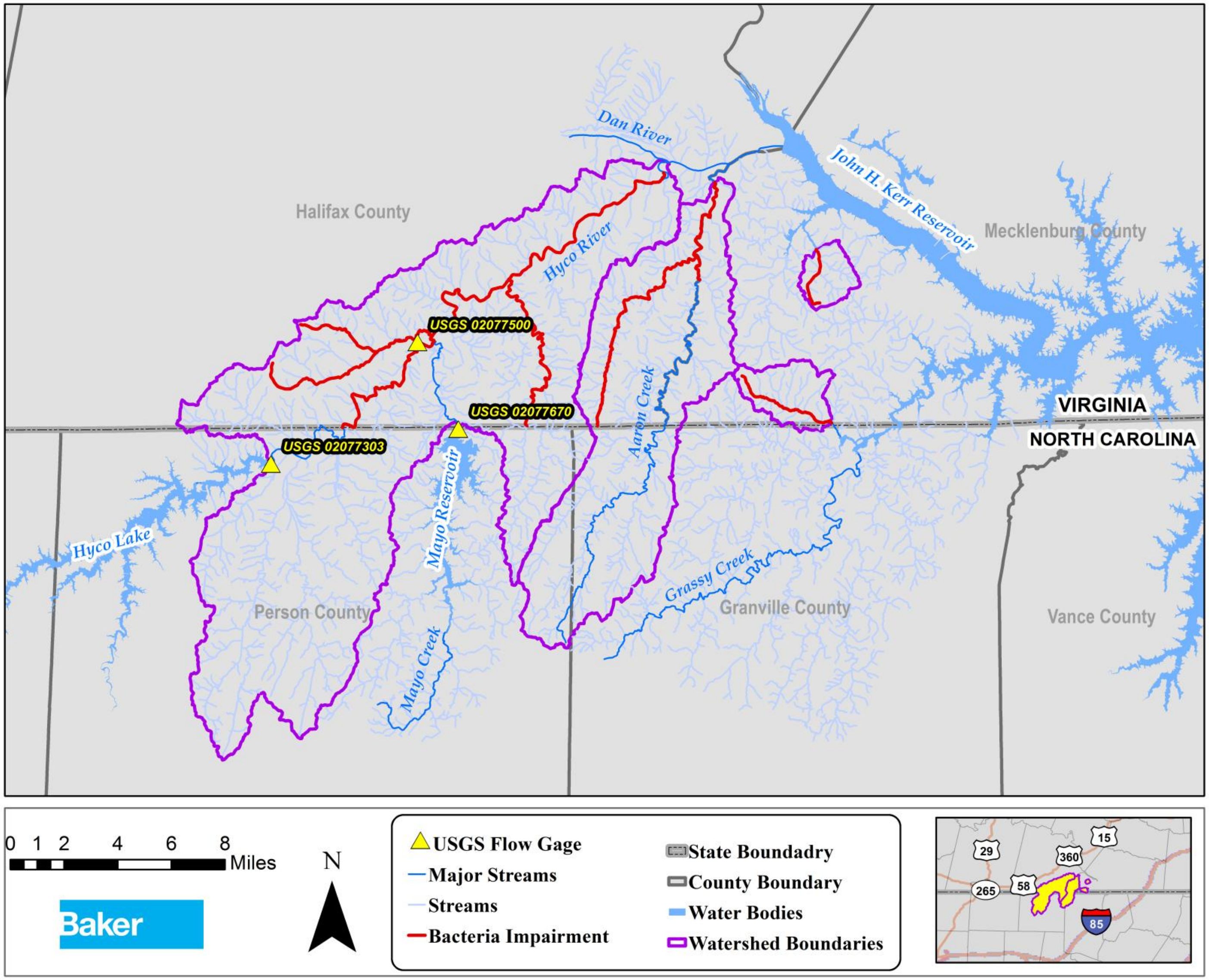


*Figure 2.9. Selected USGS Gauging Station Locations.*

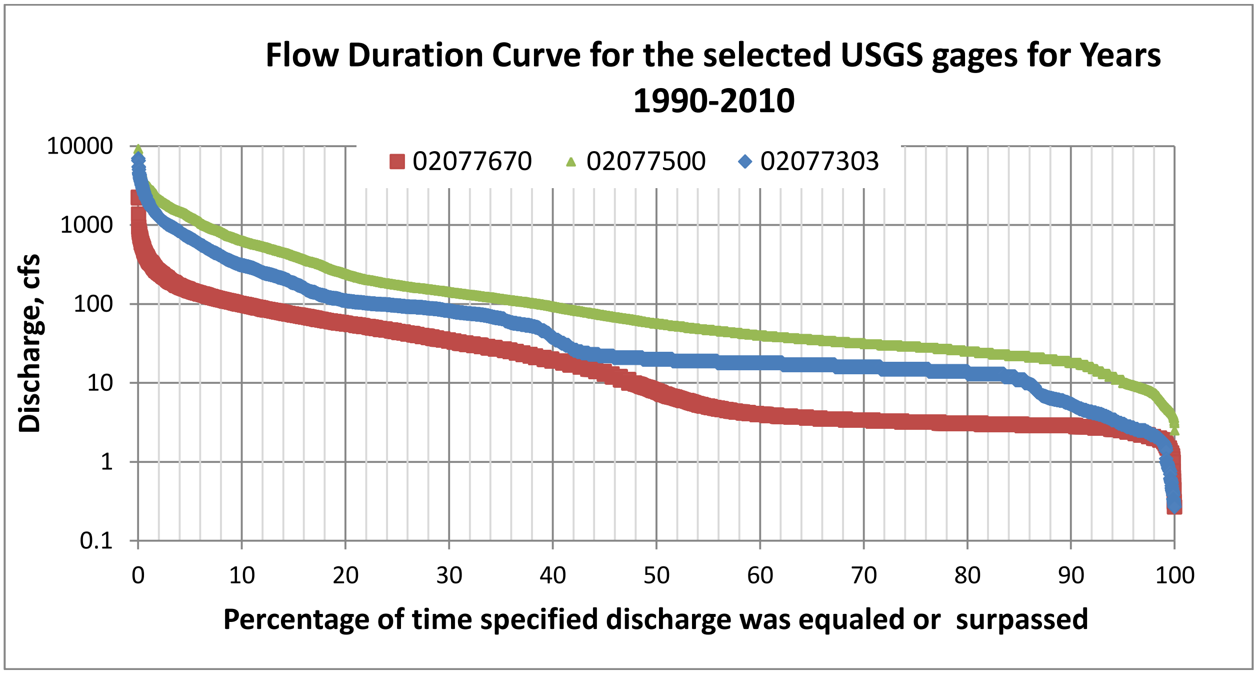


*Figure 2.10. Flow Duration Curves for the Three USGS Gaging Stations Using Data from 1990 – 2010.*

## 2.6 Water Quality

The water quality data collected in the study area were compiled from Virginia Department of Environmental Quality (VADEQ) and North Carolina's Department of Environment and Natural Resources (NCDENR). VADEQ monitors 18 different stations within the study area, while the NCDENR monitors 3 stations. Water quality data from an additional NCDENR monitoring station will be used as the boundary condition. The VADEQ stations were used to evaluate and list the impaired streams. Water quality monitoring locations are mapped in Figure 2.11 and listed in Table 2.8. Seven stations measured fecal coliform concentrations (Table 2.9). While fecal coliform is mostly not pathogenic, their presence in the water indicates contamination by fecal material. On the other hand, *E. coli* is an indicator of the presence of pathogenic organisms such as viruses, and protozoa which may cause humans harm; therefore, it is the most common indicator of disease causing organisms in recreational water. Table 2.10 summarizes the *E. coli* data taken from 14 stations.

*Table 2.8. Summary of Water Quality Monitoring Stations Information.*

| Station ID | Watershed | Location Type | Station Location | Agency | County |
|---|---|---|---|---|---|
| Virginia | | | | | |
| 4AHYC002.70 | Hyco River | River/Stream[+] | Hyco River at US 58[+] | VADEQ | Halifax |
| 4ALOL000.62 | Hyco River | River/Stream | Little Coleman Creek at Rt. 707 | VADEQ | Halifax |
| 4ACLB005.17 | Hyco River | River/Stream | Coleman Creek at Rt. 797 | VADEQ | Halifax |
| 4ACLB007.78 | Hyco River | River/Stream | Coleman Creek at Private Rd, USS Wilkerson | VADEQ | Halifax |
| 4AHYC016.70 | Hyco River | River/Stream | Hyco River at Rt. 501 S of South Boston | VADEQ | Halifax |
| 4ABOS000.13 | Hyco River | River/Stream[+] | Bowes Branch at Above Confluence With Hyco River[+] | VADEQ | Halifax |
| 4ABLU002.02 | Hyco River | River/Stream[+] | Big Bluewing Creek at North Fork Church Road[+] | VADEQ | Halifax |
| 4ACLB001.90 | Hyco River | River/Stream[+] | Coleman Creek  Close To Denniston Road And Us 501[+] | VADEQ | Halifax |
| 4ACLB001.00 | Hyco River | River/Stream+ | Coleman Creek at Route 501 | VADEQ | Halifax |
| 4AMYO001.48 | Hyco River | River/Stream[+] | Mayo Creek at Route 96 (Virgilina Road)[+] | VADEQ | Halifax |
| 4ACLB004.14 | Hyco River | River/Stream[+] | Coleman Creek at Paradise Road[+] | VADEQ | Halifax |
| 4AAAR004.72 | Aarons Creek | River/Stream[+] | Aarons Creek at Love Town Road[+] | VADEQ | Halifax |
| 4ANFA000.35 | Aarons Creek | River/Stream | North Fork, Aarons Creek at Rt 601 | VADEQ | Halifax |
| 4ALFF001.85 | Little Buffalo | River/Stream[+] | Little Buffalo Creek at US 58[+] | VADEQ | Mecklenburg |
| 4ABEE001.20 | Beech Creek | River/Stream[+] | Beech Creek at Midpoint Between Winston Road And Henrico Road+ | VADEQ | Mecklenburg |
| 4ABEE000.80 | Beech Creek | River/Stream[+] | Beech Creek at Henrico Road[+] | VADEQ | Mecklenburg |
| 4AAAR006.20 | Aarons Creek | River/Stream[+] | Aarons Creek at White House Road[+] | VADEQ | Mecklenburg |
| 4APWL001.11 | Hyco River | River/Stream[+] | Powells Creek at Faulkner Road[+] | VADEQ | Halifax |
| North Carolina | | | | | |
| N4510000 | Hyco River | River/Stream | Hyco River at Us 501 Near Denniston, VA | NCDENR | Halifax |
| N4400000 | Hyco River | River/Stream | Marlowe Creek at SR 1322 Near  Woodsdale | NCDENR | Person |
| N4250000 | Hyco River | River/Stream | Hyco River Below Afterbey Dam Near Mcgheese Mill | NCDENR | Person |
| N4590000 | Hyco River | River/Stream | Mayon Creek at SR 1501 Near Bethel Hill | NCDENR | Person |

[+] Determined using GIS data

Table 2.9. Fecal Coliform Data Summary.

| Station ID | Begin Date | End Date | No. of Samples | Min | Max | Ave | # > 400 cfu/100 mL[1] | % > 400 cfu/100 mL[1] |
|---|---|---|---|---|---|---|---|---|
| Virginia | | | | | | | | |
| 4ABOS000.13 | 4/7/2004 | 4/7/2004 | 1 | 25 | 25 | 25.0 | 0 | 0.0% |
| 4ACLB001.90 | 5/3/2006 | 5/3/2006 | 1 | 75 | 75 | 75.0 | 0 | 0.0% |
| 4AHYC016.70 | 12/10/2003 | 10/22/2013 | 56 | 25 | 2000 | 231.5 | 8 | 14.3% |
| North Carolina | | | | | | | | |
| N4250000 | 1/8/1981 | 11/5/2012 | 232 | 1 | 22000 | 143.8 | 6 | 2.6% |
| N4400000 | 8/11/1970 | 11/5/2012 | 315 | 3 | 26000 | 781.4 | 74 | 23.5% |
| N4510000 | 1/30/1985 | 11/5/2012 | 203 | 2 | 4400 | 268.4 | 28 | 13.8% |
| N4590000 | 1/30/1985 | 11/5/2012 | 204 | 1 | 1800 | 29.7 | 1 | 0.5% |

[1]Comparison with the old fecal coliform bacteria single sample maximum criterion, no exceedance found based on geometric mean

Table 2.10. E. coli Data Summary.

| Station ID | Begin Date | End Date | No. of Samples | Min | Max | Ave | # > 235 cfu/100 mL[1] | % > 235 cfu/100 mL[1] |
|---|---|---|---|---|---|---|---|---|
| Virginia | | | | | | | | |
| 4AAAR004.72 | 1/19/2011 | 12/6/2011 | 13 | 25 | 275 | 96.2 | 1 | 7.7% |
| 4AAAR006.20 | 7/16/2007 | 11/17/2008 | 10 | 25 | 280 | 53.0 | 1 | 10.0% |
| 4ABEE000.80 | 2/10/2011 | 11/27/2012 | 13 | 25 | 2,000 | 471.2 | 5 | 38.5% |
| 4ABLU002.02 | 2/10/2011 | 11/27/2012 | 11 | 25 | 1,350 | 227.3 | 2 | 18.2% |
| 4ABOS000.13 | 4/7/2004 | 4/7/2004 | 1 | 10 | 10 | 10.0 | 0 | 0.0% |
| A4CLB001.00 | 1/19/2011 | 12/6/2011 | 13 | 25 | 300 | 78.8 | 1 | 7.7% |
| 4ACLB005.17 | 1/19/2011 | 12/6/2011 | 7 | 25 | 250 | 100.0 | 1 | 14.3% |
| 4AHYC002.70 | 7/16/2007 | 12/6/2011 | 22 | 25 | 150 | 37.5 | 0 | 0.0% |
| 4AHYC016.70 | 12/10/2003 | 10/22/2013 | 41 | 10 | 2,000 | 249.9 | 7 | 17.1% |
| 4ALFF001.85 | 1/19/2011 | 12/6/2011 | 13 | 25 | 2,000 | 438.5 | 6 | 46.2% |
| 4ALOL000.62 | 1/19/2011 | 12/6/2011 | 13 | 25 | 2,000 | 388.5 | 2 | 15.4% |
| 4AMYO001.48 | 1/16/2013 | 10/22/2013 | 10 | 25 | 1,150 | 220.0 | 2 | 20.0% |
| 4ANFA000.35 | 11/6/2003 | 11/30/2010 | 19 | 25 | 2,000 | 176.3 | 2 | 10.5% |
| 4APWL001.11 | 7/2/2007 | 12/4/2008 | 12 | 25 | 300 | 93.8 | 1 | 8.3% |

[1]The 235 cfu/100 mL single sample maximum criterion allows up to 10% exceedance

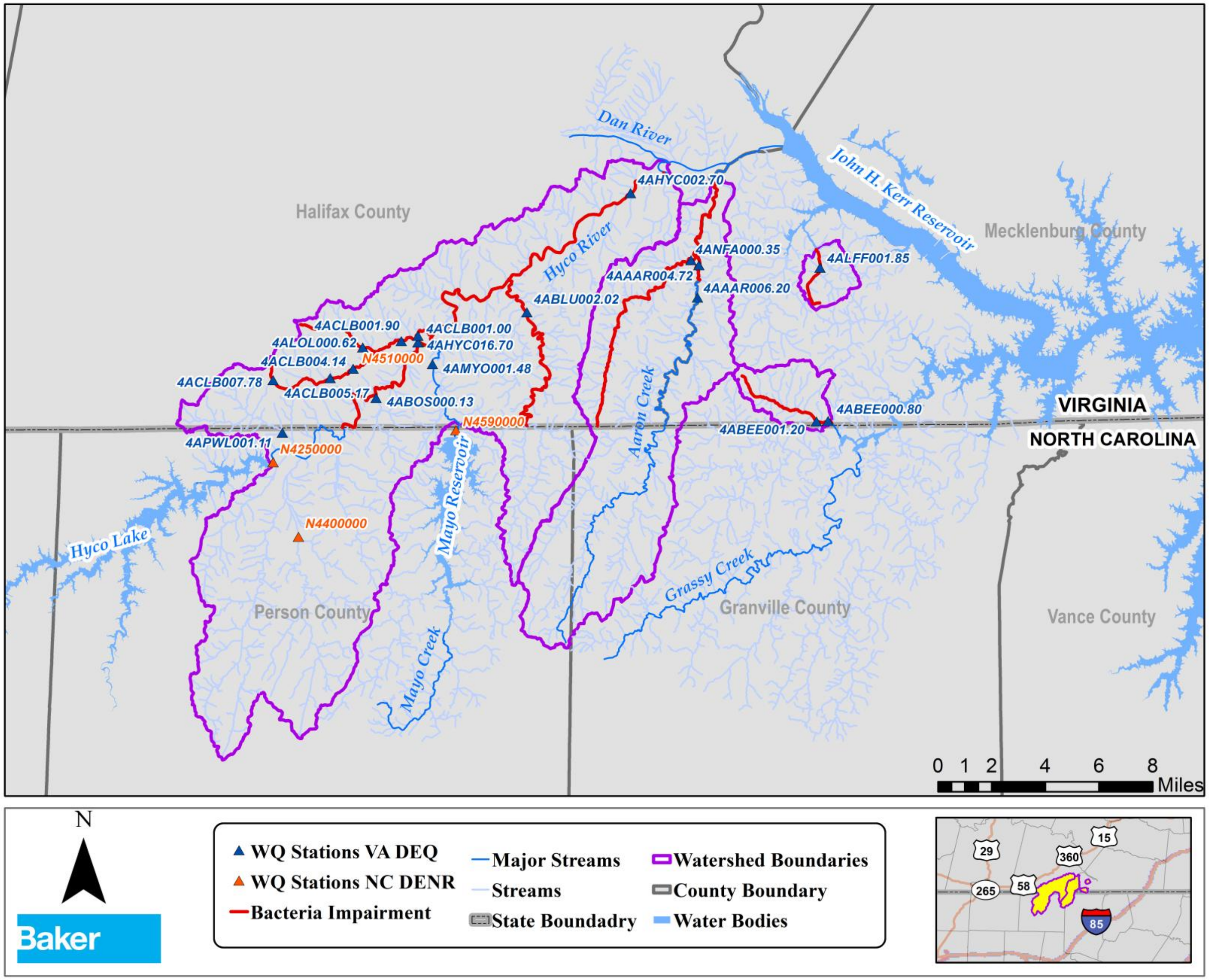


*Figure 2.11. Water Quality Monitoring Station Locations.*

## 2.7 Climate Data

The climate in the Hyco River watershed and surrounding watersheds is characterized as warm, long summers and cool, short winters. Rainfall and temperature data are available from several National Oceanic and Atmospheric Administration (NOAA) stations around the study area. This climatic data is available from NOAA's National Climatic Data Center (NCDC) website. An examination of precipitation patterns is a key part of characterizing the watershed. Describing the frequency and magnitude of rain events in conjunction with an analysis of associated runoff are important considerations. Table 2.11 lists the NCDC hourly precipitation stations within the region where the study area is located. In addition to this data, NCDC also provides daily summaries of historical data through their GHCN (Global Historical Climatology Network) -Daily database, which includes various data elements such as temperature daily maximum/minimum, temperature at observation time, precipitation, snow, evaporation, wind movement, soil temperature, cloudiness, and more. Table 2.12 lists GHCN stations near the study area. Figure 2.12 shows the location of the stations. It can be noted that no NCDC precipitation stations are in close proximity of the TMDL watersheds.

Table 2.11. Precipitation Stations (Source: NOAA NCDC).

| Station ID | Name | Elevation (m) | Latitude | Longitude | Begin | End |
|---|---|---|---|---|---|---|
| 313630 | Greensboro Piedmont Triad International Airport NC US | 271.30 | 36.0969 | -79.9432 | 6/4/1948 | 7/28/2012 |
| 310750 | B Everett Jordan Dam NC US | 94.50 | 35.6542 | -79.0706 | 5/1/1978 | 7/27/2012 |
| 311241 | Burlington 3 NNE NC US | 195.1 | 36.0955 | -79.4366 | 6/1/1948 | 7/28/2012 |
| 317079 | Raleigh State University NC US | 121.90 | 35.7944 | -78.6988 | 6/1/1948 | 7/30/2012 |
| 445120 | Lynchburg Regional Airport VA US | 286.50 | 37.3208 | -79.2067 | 8/2/1948 | 8/1/2012 |
| 440166 | Altavista VA US | 161.20 | 37.1122 | -79.2751 | 8/1/1950 | 7/31/2012 |
| 447025 | Randolph 5 NNE VA US | 107.00 | 36.98333 | -78.7 | 8/2/1948 | 3/1/1984 |
| 442250 | Danville Regional Airport VA US | 174.00 | 36.5728 | -79.3361 | 8/10/1948 | 7/27/2012 |
| 313232 | Franklinton NC US | 114.30 | 36.105 | -78.45917 | 6/1/1948 | 3/1/2006 |
| 311241 | Burlington 3 NNE NC US | 195.10 | 36.0955 | -79.4366 | 6/1/1948 | 7/28/2012 |
| 317069 | Raleigh Durham International Airport NC US | 126.80 | 35.8923 | -78.7819 | 6/1/1948 | 7/28/2012 |
| 441614 | Chatham VA US | 198.40 | 36.8224 | -79.4104 | 1/1/1961 | 8/1/2012 |

Table 2.12. Daily Summary Climatic Stations - Temperature, Wind speed, Others (Source: GHCND).

| Station ID | Name | Elevation (m) | Latitude | Longitude | Begin | End |
|---|---|---|---|---|---|---|
| USC00313969 | Henderson 2 NNW NC US | 146 | 36.3481 | -78.4119 | 06/01/1893 | 11/4/2013 |
| USC00316507 | Oxford 1 E NC US | 152 | 36.3022 | -78.6108 | 3/1/1994 | 10/31/2013 |
| USC00316510 | Oxford AG NC US | 152 | 36.3022 | -78.6108 | 3/1/1994 | 10/31/2013 |
| USC00317516 | Roxboro 7 ESE NC US | 216 | 36.3464 | -78.8858 | 1/1/1893 | 11/4/2013 |
| USC00319704 | Yanceyville 4 SE NC US | 200 | 36.3783 | -79.2544 | 12/1/1996 | 11/3/2013 |
| USC00441606 | Chase City VA US | 155 | 36.7775 | -78.4756 | 4/1/1947 | 7/31/2013 |
| USC00441614 | Chatham VA US | 198 | 36.8224 | -79.4104 | 7/1/1922 | 11/4/2013 |
| USC00441746 | Clarksville VA US | 101 | 36.6213 | -78.5506 | 03/01/1891 | 11/4/2013 |
| USC00442245 | Danville VA US | 125 | 36.5869 | -79.3886 | 03/01/1891 | 4/19/2012 |
| USC00447925 | South Boston VA US | 100 | 36.6954 | -78.8807 | 8/1/1980 | 11/4/2013 |
| USW00013728 | Danville Regional Airport VA US | 174 | 36.5728 | -79.3361 | 11/1/1945 | 11/3/2013 |

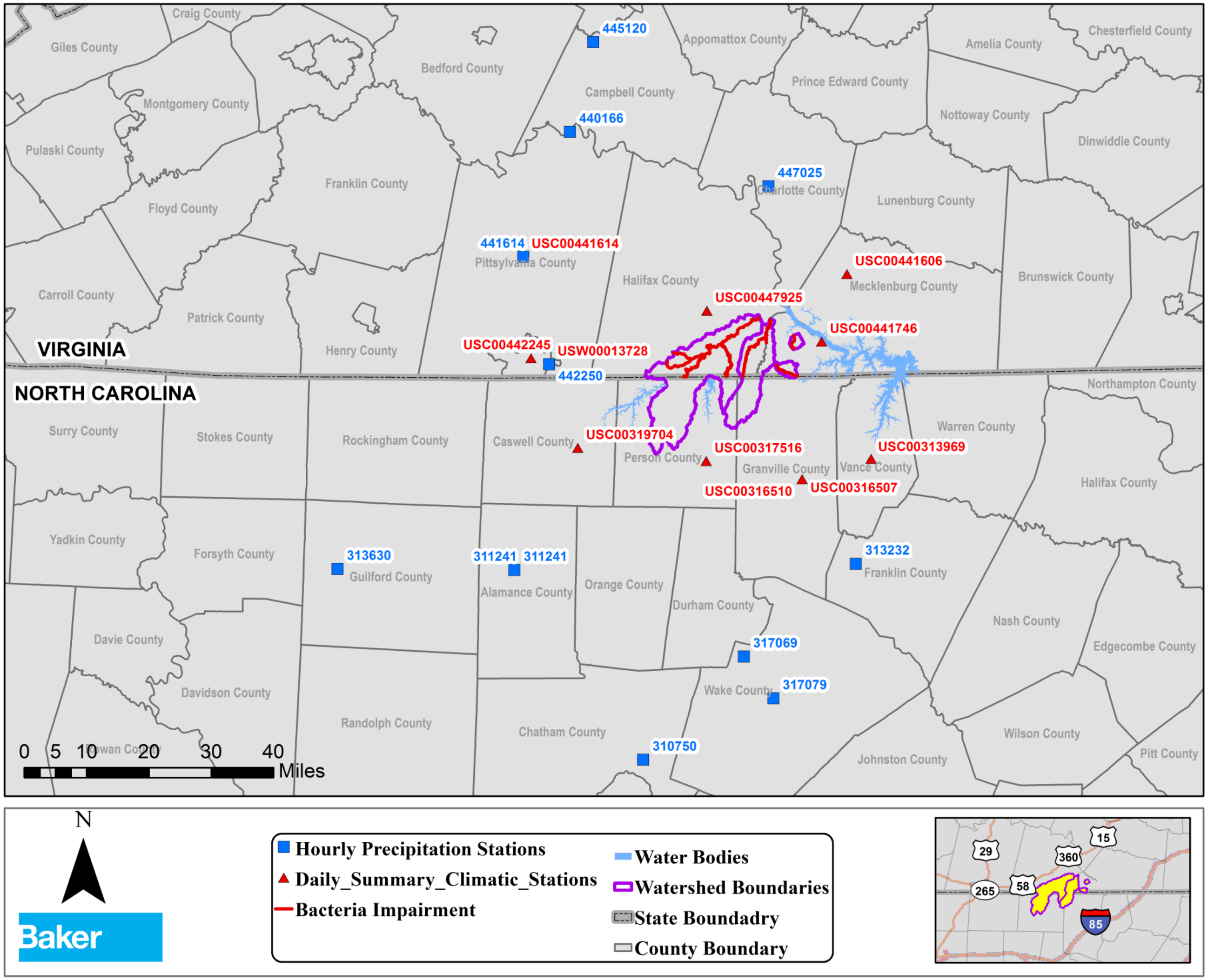


*Figure 2.12. Climatic Data Stations.*

## 2.8 Population

The county level population estimates in the years 2010 and 2012 were obtained from the U.S. Census Bureau (U.S. Census Bureau, 2010 and 2014). The data also included the percentage of changes in the population within each county. Table 2.13 shows the data for each county. Except for Granville, NC, all counties show a slight decrease in their populations within the two-year period. The population and number of housing units for the each watershed were calculated by summing up the data reported for the intersecting census blocks for 2010 census. The numbers were then projected for the year 2012, using the percentage changes reported in Table 2.13. The calculated population and number of housing units at the watershed level are shown in Tables 2.14 and 2.15, respectively.

*Table 2.13. County Demographics.*

| Statistic | Granville, NC | Halifax, VA | Mecklenburg, VA | Person, NC |
|---|---|---|---|---|
| Population, 2012 estimate | 60,436 | 35,849 | 31,749 | 39,268 |
| Population, 2010 (April 1) estimates base | 59,919 | 36,241 | 32,727 | 39,464 |
| Population, percent change, April 1, 2010 to July 1, 2012 | 0.9% | -1.1% | -3.0% | -0.5% |

*Table 2.14. Watershed Level Population.*

| Watershed | Granville, NC | Halifax, VA | Mecklenburg, VA | Person, NC | Total |
|---|---|---|---|---|---|
| Hyco River | 19 | 2,440 | 0 | 12,673 | 15,132 |
| Aarons Creek | 93 | 833 | 304 | 0 | 1,229 |
| Beech Creek | 27 | 0 | 167 | 0 | 194 |
| Little Buffalo | 0 | 0 | 315 | 0 | 315 |
| Total | 139 | 3,273 | 786 | 12,673 | 16,871 |

*Table 2.15. Watershed Level Number of Households.*

| Watershed | Granville, NC | Halifax, VA | Mecklenburg, VA | Person, NC | Total |
|---|---|---|---|---|---|
| Hyco River | 11 | 1,225 | 0 | 5,946 | 7,183 |
| Aarons Creek | 45 | 434 | 150 | 0 | 630 |
| Beech Creek | 14 | 0 | 81 | 0 | 96 |
| Little Buffalo | 0 | 0 | 139 | 0 | 139 |
| Total | 71 | 1,660 | 371 | 5,946 | 8,047 |

## 2.9 Pollutant Sources

Water quality pollutants can come from many sources, but the most common source is from wastewater discharges and contaminated runoff. Pollutants to water can be broadly categorized as resulting from point and nonpoint sources. These terms describe the nature by which pollutants enter the waterbody. Point source pollution can be defined as pollution from an identifiable discrete location such as a pipe or outfall. A point source in the watershed study area is regulated through individual permitted facilities or general domestic permits. Nonpoint pollution sources are indirect and from diffuse sources. These pollutants may enter the watershed through several non-discrete points, and can include a wide range of sources such as urban stormwater and agricultural runoff.

Note that this report focuses on the characterization of potential sources of pollution related to bacteria impairment.

### 2.9.1 Point Source Pollutants

#### *2.9.1.1 Individual Permitted Facilities*

The discharge of pollutants from an individual permitted facility is regulated through Virginia's Pollutant Discharge Elimination System (VPDES), and North Carolina's Division of Water Resources. Within the four watersheds, there are four active and two expired individual permitted facilities in Virginia, and 13 active and two expired in North Carolina. Tables 2.16 and 2.17 list the permit number and some relevant information for each permit in Virginia and North Carolina, respectively. The locations of permitted facilities and domestic permitted facilities are shown in Figure 2.13.

Table 2.16. VPDES Permitted Facilities in Virginia.

| Permit No[1] | Facility Name | Classification | Outfall No. | Design Flow (GPD) | Average Flow (GPD) | Average Concentration (cfu/100 mL) | Location | Size | River Mile | Water Body | Receiving Stream |
|---|---|---|---|---|---|---|---|---|---|---|---|
| VA0068501 | Longwood Sand Filter | History | 1 | 2,000 | No reported values | No reported values | US15, S of Clarksville at Kerr Reservoir | Minor | 0.34 | VAC-L75R | Beaverpond Creek/J.H.K. Reservoir |
| VA0062316 | Pine Grove Park STP | History | 1 | 3,000 | 1,930 | No reported values | NULL | Minor | 0.1 | VAC-L75R | Lick Branch/Unnamed Tributary. |
| VA0062421 | Newton Mobile Court Inc. | Active | 1 | 35,000 | 24,500 | 12.18 | 173 Summerville St | Minor | 1.9 | VAC-L76R | Little Buffalo Creek |
| VA0022691 | South Boston Foursquare Church | Active | 1 | 8,400 | No reported values | No reported values | NULL | Minor | 0.14 | VAC-L74R | Halfway Creek/ Unnamed Tributary. |
| VA0076830 | Virgilina Town of | Active | 1 | 35,000 | 20,043 | 4.28 | Rt 49 East of town | Minor | 0.2 | VAC-L73R | Wolfpit Run/ Unnamed Tributary |
| VA0091804 | Halifax County Schools-Cluster Springs Elem | Active | 1 | 12,000 | 5,088 | 17.95 | 7091 Huell Matthews Hwy | Minor | 0.76 | VAC-L74R | Unnamed Tributary, Halfway Creek |

[1]All permits belong to Municipal Category

Table 2.17. NPDES Permitted Facilities in North Carolina.

| NPDES ID[1] | Facility Name | Classification | Permit Issuance Date | Permit Expiry Date | Design Flow (GPD) | Size | Receiving Stream |
|---|---|---|---|---|---|---|---|
| NCG551501 | 1641 Oak Grove Road | Active | Aug-01-2013 | Jul-31-2018 | | Minor | Unnamed Tributary to Storys Creek[+] |
| NCG551343 | 166 Hickory Leaf Court | Active | Aug-01-2013 | Jul-31-2018 | | Minor | Storys Creek[+] |

| NPDES ID[1] | Facility Name | Classification | Permit Issuance Date | Permit Expiry Date | Design Flow (GPD) | Size | Receiving Stream |
|---|---|---|---|---|---|---|---|
| NCG551163 | 351 Rock Point Drive | Permit Expired | Mar-11-2010 | Jul-31-2012 | 720 | Minor | Unnamed Tributary to Satterfield Creek+ |
| NCG160186 | Adams Construction Co.- Woodsdale Plant | Active | Oct-01-2009 | Sep-30-2014 | | Minor | Unnamed Tributary to Hyco River+ |
| NC0038377 | Carolina Power & Light Co - Mayo Electric Generating Plant | Permit Expired | Oct-14-2009 | Mar-31-2012 | | Major | Mayo Creek (Mayo Reservoir) |
| NCG140091 | Chandler Concrete Incorporated | Active | Jul-01-2011 | Jun-30-2016 | | Minor | Marlowe Creek+ |
| NC0021024 | City Of Roxboro | Active | May-22-2013 | May-31-2017 | 5,000,000 | Major | Marlowe Creek+ |
| NCG110042 | City Of Roxboro | Active | Jun-01-2013 | May-31-2018 | | Minor | Marlowe Creek+ |
| NC0003042 | City Of Roxboro Water Treatment Plant | Active | May-04-2012 | Mar-31-2017 | | Minor | |
| NC0065081 | CPI USA North Carolina Roxboro | Active | Nov-09-2012 | May-31-2017 | | Minor | Unnamed Tributary of Mitchell Creek+ |
| NCS000347 | CPI USA North Carolina Roxboro | Active | Jul-09-2010 | Jul-31-2015 | | Minor | Unnamed Tributary of Mitchell Creek+ |
| NCG210288 | Georgia-Pacific Corporation | Active | Aug-01-2013 | Jul-31-2018 | | Minor | Mitchell Creek+ |
| NCG210301 | Louisiana Pacific Corp Roxbor O Osb | Active | Aug-01-2013 | Jul-31-2018 | | Minor | Bowes Branch+ |
| NCG500348 | Louisiana Pacific Corp Roxbor O Osb | Active | Aug-01-2012 | Jul-31-2015 | | Minor | Bowes Branch+ |
| NCG020722 | Woodsdale Quarry | Active | Jan-01-2010 | Dec-31-2014 | | Minor | Castle Creek+ |

+Determined using GIS data

[1]All permits belong to Private Category

#### 2.9.1.2 General Domestic Permitted Facilities

In Virginia, any person who discharges even a small volume of low potency bacteria pollutant into the surface water must apply for a general domestic permit. This permit requirement applies to any household that discharges sewage less than 1,000 gallons per day, or concentrated animal feeding operations. There are currently 23 active facilities within the impaired watershed, one of them is a new facility added recently, as summarized in Table 2.18.

*Table 2.18. General Domestic Permitted Facilities in Virginia*

| Permit No | Facility | Classification | Discharge Point | Water Body | Receiving Stream |
|---|---|---|---|---|---|
| VAG404011 | Domestic Sewage | Active | N | VAC-L73R | UT[1] to Aarons Creek |
| VAG404014 | Domestic Sewage | Active | N | VAC-L74R | Hyco River UT |
| VAG404024 | Domestic Sewage | Active | Y | VAC-L73R | Aarons Creek UT |
| VAG404044 | Domestic Sewage | Active | Y | VAC-L74R | Coleman Creek |
| VAG404045 | Domestic Sewage | Active | Y | VAC-L74R | Coleman Creek UT |
| VAG404089 | Domestic Sewage | Active | N | VAC-L74R | U.T. to Bluewing Creek |
| VAG404093 | Domestic Sewage | Active | N | VAC-L73R | Aarons Creek UT |
| VAG404179 | Domestic Sewage | Active | N | VAC-L74R | Larkin Branch UT |
| VAG407206 | Domestic Sewage | Active | N | VAC-L73R | UT of Wolfpit Run |
| VAG407229 | Domestic Sewage | Active | Y | VAC-L74R | UT to Coleman Creek |
| VAG407236 | Domestic Sewage | Active | Y | VAC-L73R | UT to Aaron's Creek |
| VAG407238 | Domestic Sewage | Active | N | VAC-L74R | UT to Hyco River |
| VAG407239 | Domestic Sewage | Active | N | VAC-L74R | UT to Hyco River |
| VAG407241 | Domestic Sewage | Active | Y | VAC-L74R | dry ditch to Hyco River |
| VAG407242 | Domestic Sewage | Active | Y | VAC-L74R | dry ditch to Hyco River |
| VAG407249 | Domestic Sewage | Active | N | VAC-L73R | UT to North Fork |
| VAG407255 | Domestic Sewage | Active | N | VAC-L73R | Aarons Creek |
| VAG407257 | Domestic Sewage | Active | Y | VAC-L74R | UT to Coleman Creek |
| VAG407266 | Domestic Sewage | Active | N | VAC-L73R | Dry ditch leading to N Fork to Aarons Creek |
| VAG407293 | Domestic Sewage | Active | N | VAC-L73R | UT, Aaron's Creek |
| VAG407314 | Domestic Sewage | Active | N | VAC-L73R | Tributary of Beech Creek |
| VAG407339 | Domestic Sewage | Active | N | VAC-L74R | UT of Blue Wing Creek |
| VAG407351 | Domestic Sewage | Active | Y | | Aarons Creek UT |

[1]UT means Unnamed Tributary

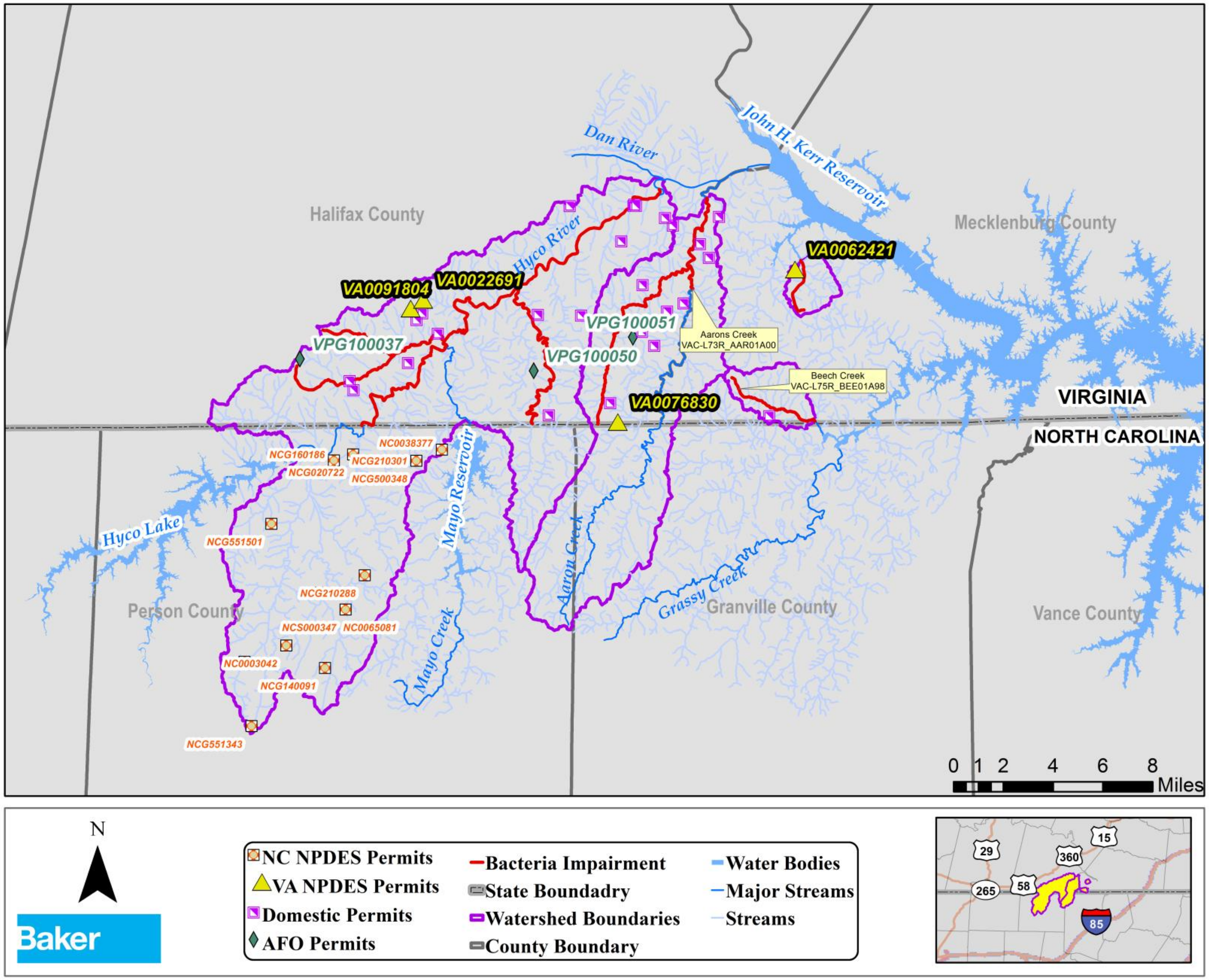


*Figure 2.13. Location of Permitted Facilities.*

## 2.9.2 Non-Point Source Pollutants

### *2.9.2.1 Septic Systems*

The number of septic systems was calculated based on the number of households and the percentage of households that use septic systems. The number of households within the watersheds was calculated using the 2010 U.S. Census data and projections for 2012. Table 2.19 shows the percentage of houses that are on public sewer, septic system (on-site sewage facilities), and other means (i.e., other than public sewer or septic systems) based on the 1990 U.S. Census survey. Note that this type of information was last collected in 1990 by U.S. Census. Using the percentages of household under each category (Table 2.19) and the number of total households, estimates of houses currently on septic systems were calculated within each watershed and are shown in Table 2.20. The numbers were discussed during the public meeting in January 2014 and with the Technical Advisory Committee which included a local health department staff.

***Table 2.19. Percentage of Houses within each County of Public Sewers, Septic Systems or Other Means.***

| County | Public Sewer | Septic System | Other Means |
|---|---|---|---|
| Virginia | | | |
| Halifax | 13.8 | 76.7 | 9.5 |
| Mecklenburg | 31.4 | 60.2 | 8.4 |
| North Carolina | | | |
| Granville | 36 | 58 | 6 |
| Person | 31 | 64 | 5 |

***Table 2.20. Number of Houses on Septic Systems.***

| Watershed | Granville, NC | Halifax, VA | Mecklenburg, VA | Person, NC | **Total** |
|---|---|---|---|---|---|
| Hyco River | 6 | 944 | 0 | 3,806 | 4,755 |
| Aarons Creek | 26 | 334 | 90 | 0 | 451 |
| Beech Creek | 8 | 0 | 49 | 0 | 57 |
| Little Buffalo | 0 | 0 | 83 | 0 | 83 |

### *2.9.2.2 Livestock*

The numbers of livestock listed in Table 2.21 were based on each county's 2007 Census of Agriculture. Fecal coliform from the animals' waste can contribute to the impairment of waters directly by excretion into a stream or indirectly via runoff. The county and local drainage livestock numbers were discussed for evaluation and adjusted based on feedback received from the first public meeting, attended by local NRCS district staff as well as follow up conversations with district staff.

*Table 2.21. Livestock Statistics from NASS.*

| Statistic | Granville, NC | Halifax, VA | Mecklenburg, VA | Person, NC |
|---|---|---|---|---|
| Cattle and Calves | 12,150 | 18,786 | 22,126 | 7,536 |
| Beef Cows | 4,304 | 10,746 | 12,275 | D* |
| Milk Cows | 285 | 247 | 783 | D* |
| Other Cattle | 7,561 | 7,793 | 9,068 | 3,169 |
| Goats | 1,114 | 983 | 724 | 1,127 |
| Hogs and Pigs | 7,692 | 16,070 | D* | 4,470 |
| Horses and Ponies | 1,206 | 793 | 702 | 431 |
| Sheep and Lambs | 699 | 111 | 51 | 256 |

**D – Withheld to avoid disclosing data for individual farms*
*Source: County level livestock based on 2007 Agricultural Census*

To estimate the livestock population within each watershed, a ratio of pastureland within the watershed to the total pastureland within the county was calculated. This ratio was multiplied by the total livestock population in the county to estimate the livestock population within the TMDL watershed. The estimated livestock populations by livestock type within each watershed are shown in Table 2.22.

*Table 2.22. Livestock Populations within TMDL Watersheds.*

| Watershed | Cattle | Goats | Sheep | Horse |
|---|---|---|---|---|
| Aarons Creek | 1,838 | 133 | 40 | 108 |
| Beech Creek | 362 | 12 | 1 | 12 |
| Hyco River | 2,493 | 325 | 64 | 168 |
| Little Buffalo | 232 | 8 | 1 | 8 |

### 2.9.2.3 Pets

Fecal coliform from pets can be transported to streams from runoff. Table 2.23 summarizes the pet population in each watershed by pet type. Numbers of pets in each watershed were calculated by multiplying the number of households in each watershed (Table 2.23) by a pet type factor from the American Veterinary Medical Association (AVMA, 2013). The pet factors are summarized in Table 2.24. The pet numbers were discussed and verified by consensus during the first public meeting.

*Table 2.23. Pet Populations within TMDL Watersheds.*

| Watershed | Households | Dogs | Cats |
|---|---|---|---|
| Aarons Creek | 630 | 368 | 402 |
| Beech Creek | 96 | 56 | 61 |
| Hyco River | 7,183 | 4,195 | 4,582 |
| Little Buffalo | 139 | 81 | 88 |

**Table 2.24. Formulas for Estimating the Number of Pet-Owning Households Using National Percentages.**

| Animal | Factor |
|---|---|
| Dogs | Number of dog-owning households = .584 x total number of households |
| Cats | Number of cat-owning households = .638 x total number of households |

### 2.9.2.4 Wildlife

Another important source of fecal coliform/*E. coli* is wildlife within the watershed. The population of various wildlife species is calculated using the information available from previous EPA-approved Virginia TMDL reports. The wildlife populations within the watersheds are calculated using the suitable habitat within the watershed. The typical wildlife densities and the suitable habitats are listed in Table 2.25. Table 2.26 provides the estimates of wildlife within the watersheds based on the typical densities shown in Table 2.25. Wildlife numbers were discussed and verified during the first public meeting. A lengthy discussion on impacts from wild coyote's which are a nuisance to livestock was held. It was mentioned during the public meeting that both Halifax and Mecklenburg counties have both issued bounties for coyotes in the past in an attempt to control their increasing population. The idea is that the data the counties have collected through the bounty program can be used to estimate the number of coyote population. An investigation of available bounty data from Mecklenburg county indicated that there are about 85 coyotes within the county. Using the area ratio between the county and the watersheds, the number of coyotes within each of the watersheds was then estimated to be 20, 8, 1, and 1 for Hyco River, Aaron's Creek, Beech Creek, and Little Buffalo Creek watersheds, respectively. These values are considerably less than the wildlife populations listed in Table 2.26 and their impact insignificant. Pollutant contribution from coyotes was therefore, not included in the model.

**Table 2.25. Wildlife Habitat and Typical Densities.**

| Wildlife Species | Suitable Habitat | Typical Population Density |
|---|---|---|
| Deer | Whole watershed except open water, high intensity development | 0.047 animals/acre |
| Raccoon | Within 600 feet of streams and ponds | 0.07 animals/acre |
| Muskrat | Within 66 feet of streams and ponds | 2.75 animals/acre |
| Beaver | Within 66 feet of streams and ponds | 4.8 animals/mile of stream |
| Goose | Whole Watershed | 0.02 animals/acre |
| Wild Turkey | Forest | 0.01 animals/acre |

**Table 2.26. Estimates of Wildlife Population within the Watersheds.**

| Watershed | Hyco River | Aarons Creek | Beech Creek | Little Buffalo Creek |
|---|---|---|---|---|
| Deer | 5,168 | 1,148 | 208 | 102 |
| Goose | 2,200 | 489 | 84 | 48 |
| Wild Turkey | 673 | 138 | 106 | 7 |
| Raccoon | 4,500 | 1,038 | 106 | 39 |
| Muskrat | 21,611 | 4,995 | 470 | 167 |
| Beaver | 2,379 | 561 | 51 | 18 |

# 3.0 MODELING APPROACH

This section describes the hydrologic and the water quality modeling approaches of developing bacteria TMDLs for the impaired segments in the Hyco River, Aarons Creek, Little Buffalo Creek, and Beech Creek watersheds. The primary focus of this section is to present the assumptions and simplifications, sources of pollutants, calibration, validation and existing loads calculations. Four separate models have been set up for the four groups of impaired segments as shown in Figure 1.1 and as listed below:

v. The Hyco River watershed including Hyco River and Coleman Creek, Little Coleman Creek and Big Bluewing Creek
vi. Aarons Creek watershed including Aarons Creek and North Fork Aarons Creek
vii. Little Buffalo Creek watershed including Little Buffalo Creek
viii. Beech Creek watershed including Beech Creek

## 3.1 Modeling Goals and Model Selection

The goal of this task is to develop a model that can be used as a tool to fill data gaps, to help understand the relationship between pollutant sources and in-stream concentrations, to simulate the effects of the temporal and spatial variability of watershed conditions, and to evaluate pollutant reduction scenarios to achieve TMDL allocations. The model must sufficiently fulfill the scope and objectives that are described in more detail as follows:

i. represent true watershed characteristics of the impaired segments
ii. ensure appropriate applications of topographic, hydrographic, landscape, climate, and water quality variables in a watershed system over a certain period of time
iii. represent potential point and non-point pollution sources of bacteria and their contributions, including fecal coliform
iv. use meteorological, flow, and water quality time series data to accurately simulate the time varying nature of environmental conditions
v. quantitatively estimate the in-stream pollutant concentrations under various hydrologic conditions
vi. allow for calibration by comparing simulated data with observed values under different climatic and watershed conditions
vii. allow direct comparison between in-stream conditions and water quality standards and
viii. finally be used as a primary decision support tool for TMDL development, allocation, and a subsequent implementation program in the selected watersheds.

## 3.2 Modeling Strategy

The Hydrologic Simulation Program – FORTRAN (HSPF) has become the model of choice for developing bacteria TMDLs in Virginia because it is one of the very few models that have the capabilities to fulfill the modeling objectives listed above, and to help provide statewide consistency where possible.

HSPF provides users exceptional flexibilities in defining spatial and temporal variability of watershed characteristics, hydrologic and water quality modeling capabilities, proper representation of individual point sources, climatic data handling capabilities, track water and pollutant fate and transport from land-based sources to water bodies by sources and pathways and ability to calibrate and validate the model. Finally, the model can be modified in many ways to represent watershed- and subwatershed- specific pollutant reduction scenarios for source control, management or treatment types, and to develop TMDL allocations.

This section describes the procedure for completing the modeling task in a comprehensive and organized way. Data processing tools and their applications are also discussed in detail. Each watershed has been divided into a number of sub-watersheds that include major tributaries, impaired segments and point source discharges. Then, the model has been sequentially calibrated for flow and bacteria. HSPF generates non-point source runoff and loads from land sources and routes them to adjacent stream segments. Flow in the stream segments is routed downstream along with water quality constituents. Appropriate land-based and in-stream processes have been selected and parameterized through model calibration and sensitivity analyses. Modeled streamflow and pollutant concentrations have been compared with observed data from flow gages and water quality monitoring stations for model calibration and validation.

### 3.2.1 Data Development and Modeling Support Tools

As mentioned earlier, the HSPF has been used for TMDL development and allocation in the Hyco River, Aarons Creek, Little Buffalo Creek and Beech Creek impaired watershed models. To assist in watershed-based hydrologic analysis for TMDL development for impaired stream watersheds, an integrated GIS-based data analysis and modeling tool has been used. For this purpose, the Better Assessment Science Integrating Point and Non-point Sources (BASINS) software (USEPA, 2000), which is an EPA-supported public domain product allowing users to perform GIS-based data processing and model input preparation has been used. BASINS utilizes the MapWindow GIS environment and integrates several data analysis tools and environmental modeling software. Alternative methods and tools have also been used to augment BASINS during watershed management and input data preparation tasks. For time series data preparation and management, the Weather Data Management Utilities (WDMUtil) tool, which is integrated with BASINS, has been used. Important modeling and data preparation tasks are listed below along with the software names.

- GIS data management -- ArcGIS 10.0+ (ESRI, 2014)
- Watershed management -- BASINS 4.1 (USEPA, 2003)
- Hydrologic model interface -- BASINS 4.1
- Climate time series data processing – WDMUtil (Hummel, P. et al., 2001)
- Water quality modeling and TMDL development -- HSPF (Duda, P. et al., 2001)
- Model calibration -- HSPEXP/PEST (USGS, 2014; Doherty, J. et al., 2014)

### 3.2.2 Description of the Impaired Watersheds

The Hyco River watershed spans across the boundary between Virginia and North Carolina. The impaired segment of the Hyco River, along with its three impaired tributaries -- the Coleman Creek, the Little Coleman Creek, and the Big Bluewing Creek, are located in Halifax County, VA. A major upstream portion of the Hyco River watershed is located in Caswell, Person and Orange

Counties, NC. The impaired segments have a total length of approximately 44.7 miles and the entire drainage area of the Hyco River falls within the area of the Lower Dan River watershed (USGS Cataloging Unit 03010104). The impaired segment of the Hyco River flows directly into the Dan River upstream of the John H Kerr Reservoir.

The Aarons Creek watershed is also located in the Lower Dan River HUC. Aarons Creek has one impaired tributary (North Fork Aarons Creek), which starts near the state boundary and flows north into the Dan River downstream of the Hyco River confluence. The total length of the two impaired segments is approximately 14.8 miles. The Aarons Creek watershed is located in three counties -- Halifax County and Mecklenburg County, VA, and Granville County, NC.

Little Buffalo Creek is an impaired stream, which has a small watershed to the east of the Aarons Creek watershed. The length of the impaired segment of the Little Buffalo Creek is only 2.6 miles. The Little Buffalo Creek watershed is located within the Lower Dan River Watershed and in Mecklenburg County, VA. Little Buffalo Creek joins Buffalo Creek before flowing into the Dan River.

The Beech Creek impaired segment is located very close to the border between Virginia and North Carolina. The stream has a total length of about 4.3 miles. The Beech Creek watershed is located in Mecklenburg County, VA and Granville County, NC and is a part of the Middle Roanoke watershed (USGS HUC 03010102).

3.2.3 Spatial Extent and Boundary Conditions

This project involves the development of bacteria TMDLs for eight impaired segments. In the Hyco River watershed, two segments on the main stem and three tributaries (Coleman Creek, Little Coleman Creek, and Big Bluewing Creek) are listed as impaired. The headwaters of the Hyco River are located in North Carolina. Aarons Creek, which is an impaired stream located at the east of the Hyco River watershed, meets a long impaired tributary, North Fork Aarons Creek, before flowing into the lower Dan River. Little Buffalo Creek, which is also a small impaired stream located further to the east, flows into the Buffalo Creek before finally reaching the John H Kerr Reservoir, eventually. All of these streams are located in the same hydrologic unit -- the Lower Dan River watershed (HUC ID 03010104). Beech Creek is the only impaired segment in this group which is located in a different hydrologic unit -- the Middle Roanoke watershed (HUC 03010102). This segment flows from Virginia to North Carolina and then returns to Virginia before flowing into the John H Kerr Reservoir, downstream of the other tributaries in this report.

Since these TMDLs will not set bacteria load allocations for watershed areas in North Carolina and all necessary data for the development of TMDLs are not readily available for the parts of the watersheds that are located in North Carolina, it is appropriate to set the upstream boundaries of the models as close to Virginia's border as possible. Under such circumstances, the upstream boundary conditions must be defined by observed flow and water quality time series data. However, the lack of adequate observed flow and water quality data in North Carolina requires hydrologic and water quality modeling for the entire watershed except for the

Hyco Lake and Mayo Creek sub-watersheds. Flow data from the Hyco River below Abay Drive near McGehees Mill, NC gage (USGS gage ID 02077303) was used as an upstream boundary condition of the watershed model to represent the flow contribution of the drainage area upstream of the gage which includes the Hyco Lake. Similarly, the Mayo Creek near Bethel Hill, NC gage (USGS gage ID 02077670) was used to define another upstream boundary condition to represent the flow contribution of the drainage area upstream of the gage which includes the Mayo Creek and Reservoir.

## 3.3 Model Setup

The modeling task is divided into three phases:

- Hydrologic modeling,
- Water quality modeling, and
- TMDL allocation

The earlier chapters described the data collection and watershed characterization steps that lead to the next few steps as follows:

- Hydrologic Model Setup
    - Watershed delineation
    - Initial model setup with physical input data and estimated initial parameter values
    - Model calibration
    - Model validation
- Water Quality Model Setup
    - Input data preparation, primarily in Fecal Tool
    - Estimating quality parameters specific to fecal coliform bacteria
    - Model calibration
    - Model validation

The following sections explain each step in detail.

### 3.3.1 Hydrologic Model Setup

#### *3.3.1.1 Watershed Delineation and Data Development*

The purpose of watershed delineation is to truly represent the hydrologic characteristics of the drainage area and to ensure sufficient modeling accuracy in developing the bacteria TMDL. Watershed delineation has been performed using an ArcGIS based Watershed Delineation Tool, which utilizes the DEM data representing basin topography and the NHD hydrographic data depicting natural stream center lines. The outlet points that are required for watershed delineation and stream segmentation have been specified considering the locations of the following features.

- Stream confluences
- USGS flow gage locations
- VADEQ water quality monitoring stations
- Significant changes in stream or sub-watershed characteristics (i.e. area, width, slope, etc.)

For this TMDL, the boundaries of the Hyco River, Aarons Creek, Little Buffalo Creek and Beech Creek watersheds have been determined on the basis of NHD hydrographic flow lines and topographic data. Setting the upstream boundary of Hyco River and its watersheds near the state boundary line would be ideal for developing TMDLs. However, the number of long-term continuous flow gages are found to be inadequate compared to the spatial distribution of NHD hydrographic tributaries which extend beyond the VA boundary and fall into North Carolina. In such cases, the entire drainage area of all the connected tributaries has been included in the model, resulting in the inclusion of large areas of North Carolina.

Although the HSPF model does not have a direct input for sub-watersheds, sub-watershed boundaries define the physical connectivity of land uses to stream reaches and reservoirs and also the acreage of each land use type that drains to a reach. Overlaying sub-watershed boundary data layer on the GIS land use coverage helps to determine the acreage of different land uses in each sub-watershed.

#### 3.3.1.2 Land Use Reclassification

The HSPF model requires that each land use represented in the model is correctly parameterized for hydrology and water quality simulations. As the number of land use classes increases, parameterizing the model becomes a daunting task requiring substantially more data and effort to setup and calibrate the model. The recommended approach is to simplify the model by including only the land uses that cover large areas of the watershed and contribute as the significant sources of runoff and pollutant loads. Therefore, the listed 16 NLCD land use classes are reclassified as shown in Table 3.1 to reduce the number of land uses to be modeled. Hay land is distinguished from pastureland by using the 2012 National Agricultural Statistics Service (NASS) Crop Data Layer to provide additional information that will be useful during development of the implementation plan to quantify pasture areas where livestock exclusion fencing is needed.

***Table 3.1. Planned Reclassification Scheme to Convert 2006 NLCD Land Use Classes to Fewer Classes for Modeling.***

| Hyco River Watershed NLCD Land Use Types | Reclassified Land Use |
|---|---|
| Open Water | Water/Wetland |
| Developed, Open Space | Developed Urban Area |
| Developed, Low Intensity | Low Density Residential |
| Developed, Medium Intensity | Medium Density Residential |
| Developed, High Intensity | High Density Residential |
| Barren Land (Rock/Sand/Clay) | Barren Land (Rock/Sand/Clay) |
| Deciduous Forest | Forest |
| Evergreen Forest | Forest |
| Mixed Forest | Forest |
| Shrub/Scrub | Forest |
| Grassland/Herbaceous | Pasture |

| Hyco River Watershed NLCD Land Use Types | Reclassified Land Use |
|---|---|
| Pasture | Pasture |
| Hay | Hay |
| Cultivated Crops | Crop |
| Woody Wetlands | Water/Wetland |
| Emergent Herbaceous Wetlands | Water/Wetland |

#### 3.3.1.3 Hydrographic Data and F-Table Generation

The hydrographic data that show the stream networks and contain stream characteristics have been generated from the NHD flow lines during the delineation of the Hyco River, Aarons Creek, Little Buffalo, and Beech Creek watersheds. These stream data have been used for HSPF model input preparation and TMDL development. Information regarding the reach number, reach name, and length of each stream segment of the Hyco River, Aarons Creek, Little Buffalo, and Beech Creek are included in the NHD database. Due to the large amount of data, reach information for Hyco River, Aarons Creek, Little Buffalo Creek, and Beech Creek are presented in Appendix A.

In addition to stream reach connectivity, length, slope, etc., the HSPF model requires a table defining the depth-volume-discharge relationship for each reach. These tables, called Function-Tables or F-Tables in the User Control Input (UCI) file, are used to simulate hydraulics or flow routing through the stream and reservoir network. The Hyco River and its tributaries were represented as irregular channels based on actual data. Channel geometry, i.e. depth and surface area for an individual stream has been estimated from the DEM using GIS software and the stage-flow relationship required by the HSPF model has been computed using Manning's equation using an estimated roughness coefficient.

#### 3.3.1.4 WDM Preparation

The Watershed Data Management (WDM) file is a special binary file format commonly used to store large volumes of time series data. Historic time series input data (e.g. rainfall, evapotranspiration), model boundary condition and calibration data (e.g. stream flow measurements), point source discharge data, model state variables, and outputs are stored in WDM files. Data in a WDM file can be easily linked to model input (i.e. UCI file), managed, modified and exported to any tabular forms. EPA's BASINS provides the Watershed Management Utilities (WDMUtil) tool to prepare, populate and manage a WDM file. Climatic data that are available from local stations are discussed in Section 2.7. Modeling flow and water quality to develop TMDLs in Virginia, particularly those in the Hyco River watershed, require rainfall data at a small time interval. Although an hourly time step is commonly used for HPSF modeling the proximity of the precipitation gage(s) to watershed plays the most important role in accurately simulating flows. Since none of the hourly precipitation stations are located within the Hyco River watershed and the nearest hourly precipitation gage (COOP ID: 317069) at Raleigh Durham International Airport is located 50 miles away, the final selection of the rainfall data, whether obtaining directly from one or more stations or averaging rainfall data from multiple stations, was made during the model setup and calibration processes. Analyzing the gage locations, and the extent, time interval and the quality of the data, revealed that none of the precipitation stations for the Hyco River watershed seemed adequate for long-term hydrologic modeling and TMDL development. The USGS precipitation gage at Double Creek near Roseville, NC (USGS 02077240) recorded hourly data until 1983 -- a time long before the period of the Hyco River model. The data availability of the USGS rainfall gage at John H. Kerr Reservoir at Dam near Boydton, VA (USGS 02079490) was limited to the period after October 1, 2009. Therefore, as an alternative, precipitation data obtained from the Tropical Rainfall Measuring Mission (TRMM), which is a joint mission between National Aeronautics and Space Administration (NASA) and the Japan Aerospace Exploration Agency (JAXA) designed to monitor and study tropical rainfall, were analyzed and evaluated. TRMM provides continuous local precipitation data at three-hour intervals making the data most suitable for hydrologic modeling of Hyco River, Aarons Creek, Little Buffalo, and Beech Creek. TRMM data (version 7) provide gridded estimates on a 3-hour temporal resolution and a 0.25-degree by 0.25-degree spatial resolution in a global belt extending from 50 degrees South to 50 degrees North latitude. These data are extensively quality checked and validated using ground based precipitation measurements. Figure 3.1 shows the location and extent of the TRMM grids near Hyco River watershed.

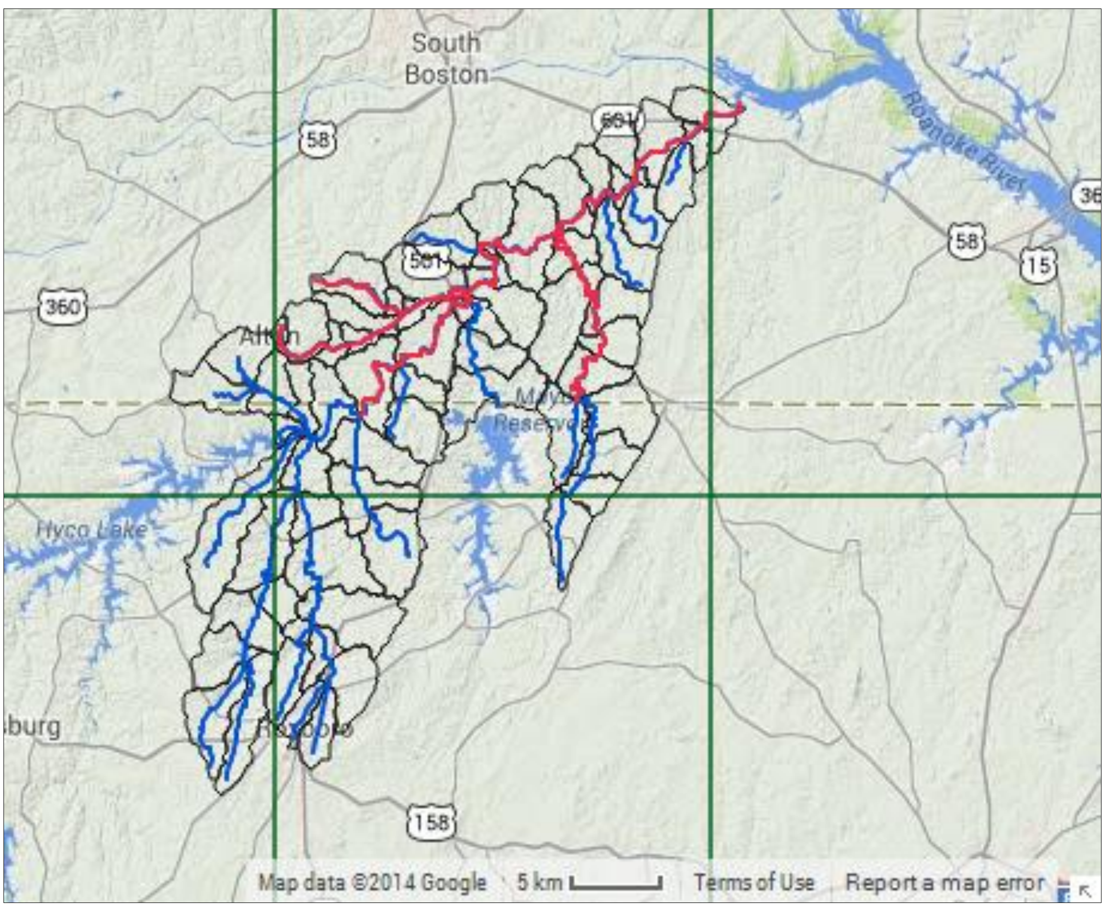


*Figure 3.1. The Location and Extent of TRMM Grids near the Hyco River Watershed*

#### 3.3.1.5 Hydrologic Calibration

Hydrologic calibration of the HSPF model involves adjustment of model parameters to control various flow components (e.g. surface runoff, interflow and base flow, and the shape of the hydrographs). It also makes simulated values match observed flow conditions during the desired calibration period. The calibration process compares the model results with observed data to ensure that the model output is accurate for a given set of conditions.

The Hyco River HSPF model has been calibrated using the daily average flow data observed at Hyco River near Denniston, VA gage (USGS gage ID 02077500). Based on the NHD hydrographic data and USGS HUC boundary, this observed station has a drainage area of about 91.4 square miles. Stream flow data from 2005 through 2012 have been divided into two periods, one for model calibration and another for model validation. Lack of flow data from the USGS gage at Hyco River below Abay Drive Near McGehees Mill, NC (USGS gage ID 02077303) prior to October 2004 restricted the modeling period between October 2004 and December 2012. The hydrologic calibration of Hyco River HSPF model has been performed for a period of four years from January 1, 2009 through December 31, 2012 and the model validation has been performed for a period of four years from January 1, 2005 through December 31, 2012. Since no other flow gage is located in the Aarons Creek, Little Buffalo, and Beech Creek watersheds, a paired watershed approach has been used to apply the calibrated and validated hydrologic model to the Aarons Creek, Little Buffalo Creek, and Beech Creek watersheds. Since both the Hyco River and the other impaired watersheds (HUCs) are part of the Southern Piedmont hydrologic region, as defined by the USGS for estimating flood magnitude and frequency for the National Flood Frequency Program, use of the paired-watershed approach in any ungaged watersheds within this hydrologic region can be justified.

Hydrologic calibration of the model has been performed by comparing the simulated and observed quantities for selected eight hydrologic components namely,

- Total runoff, in inches (i.e., runoff volume/drainage area)
- Total of highest 10% flows, in inches
- Total of lowest 50% flows, in inches
- Total storm volume, in inches
- Base-flow recession rate
- Summer flow volume, in inches
- Winter flow volume, in inches, and
- Summer storm volume, in inches

Specific numeric targets, as listed below, have been checked to achieve a comprehensive calibrated and validated model.

- Error in 50% lowest flows +/-10%
- Error in 10% highest flows +/-15%
- Error in low flow recession +/-10%
- Summer storm volume error +/-15%
- Error in total volume +/-10%

### 3.3.1.6 Hydrologic Calibration Results

The Hyco River HSPF model hydrology has been calibrated using HSPEXP software. After the completion of each iteration of the model, summary statistics have been calculated to compare model results with observed values. The calibration parameters have been adjusted on the basis of the built-in rules which were derived from the experience of expert modelers and listed in the HSPEXP user manual (Lumb and Kittle, 1993).

Using the recommended criteria (mentioned in the previous section) as target values for an acceptable hydrologic calibration, the Hyco River HSPF model has been calibrated for January 2009 to December 2012 at the USGS flow station 02077500 (Hyco River near Denniston, VA). The model calibration results at USGS Station 02077500 are presented in following Table 3.2, showing the simulated and observed values for eight flow characteristics. A summary of error statistics for five flow conditions is presented in Table 3.3. The model results and the observed daily average flow at the calibration station (USGS 02077500) are plotted in Figure 3.2. As the tables show, the small differences between the simulated and the observed values (e.g. the total simulated runoff of 118.9 inches during 4-year calibration period as opposed to an observed value of 116.7 inches) assure a very good model performance and give high confidence in model results.

*Table 3.2. Hyco River HSPF Model Hydrologic Calibration Summary at USGS Station 02077500.*

| Parameter | Unit | Value | |
|---|---|---|---|
| | | Simulated | Observed |
| Total Runoff | inches | 118.9 | 116.7 |
| Total of Highest 10% Flows | inches | 70.8 | 75.4 |
| Total of Lowest 50% Flows | inches | 7.7 | 7.9 |
| Total Storm Volume | inches | 45.6 | 46.8 |
| Base-flow Recession Rate | | 1.0 | 1.0 |
| Summer Flow Volume | inches | 15.3 | 14.5 |
| Winter Flow Volume | inches | 45.2 | 47.4 |
| Summer Storm Volume | inches | 9.9 | 9.6 |

*Table 3.3. Hyco River HSPF Model Hydrologic Calibration Result -- Error Statistics at USGS Station 02077500.*

| Parameter | Unit | Value | Criteria |
|---|---|---|---|
| Error in 50% Lowest Flows | % | -3 | ±10% |
| Error in 10% Highest Flows | % | -6.1 | ±15% |
| Error in Low Flow Recession | % | 0 | ±10% |
| Summer storm volume error | % | 5.7 | ±15% |
| Error in Total Volume | % | 1.9 | ±10% |

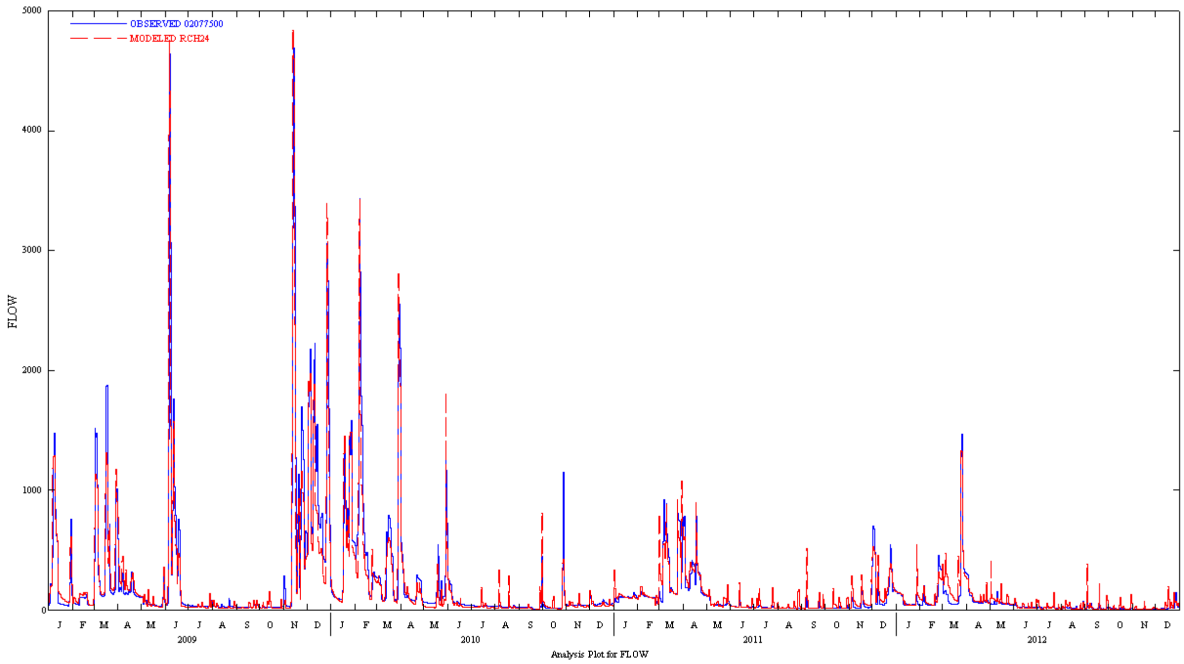


*Figure 3.2. Hyco River HSPF Model Hydrologic Calibration Results at USGS Station 02077500.*

### *3.3.1.7 Hydrologic Validation*

Model validation establishes the credibility of the hydrologic model developed through model calibration. The validation process compares the model output to an observed dataset, which is different from the one used in the calibration process. The outcome of the process demonstrates the model's prediction accuracy.

As mentioned earlier, due to unavailability of sufficient gages in unregulated streams, observed flow data at the Hyco River near Denniston, VA gage (USGS gage ID 02077500) have been divided into two time periods to provide two independent data sets for model calibration and validation. The numeric targets for model validation are similar to those listed above under Hydrologic Calibration.

The Hyco River HSPF Model hydrology validation has been done for the period of January 1, 2005 to December 31, 2008. Similar to the model calibration results, the validation result statistics summary have been listed in following Table 3.4 and Table 3.5. Figure 3.3 illustrates the final model output and observed flow within the total validation period.

*Table 3.4. Hyco River HSPF Model Hydrologic Validation Summary at USGS Station 02077500.*

| Parameter | Unit | Value | |
|---|---|---|---|
| | | Simulated | Observed |
| Total Runoff | inches | 103.0 | 104.5 |
| Total of Highest 10% Flows | inches | 61.3 | 71.0 |
| Total of Lowest 50% Flows | inches | 7.6 | 7.0 |
| Total Storm Volume | inches | 30.5 | 31.5 |
| Base-flow Recession Rate | | 1.0 | 0.96 |
| Summer Flow Volume | inches | 9.0 | 7.0 |
| Winter Flow Volume | inches | 35.1 | 33.4 |
| Summer Storm Volume | inches | 2.5 | 2.4 |

*Table 3.5. Hyco River HSPF Model Hydrologic Validation Result -- Error Statistics at USGS Station 02077500.*

| Parameter | Unit | Value | Criteria |
|---|---|---|---|
| Error in 50% Lowest Flows | % | 8 | ±10% |
| Error in 10% Highest Flows | % | -13.7 | ±15% |
| Error in Low Flow Recession | % | 0 | ±10% |
| Summer Storm Volume Error | % | 8.3 | ±15% |
| Error in Total Volume | % | -1.4 | ±10% |

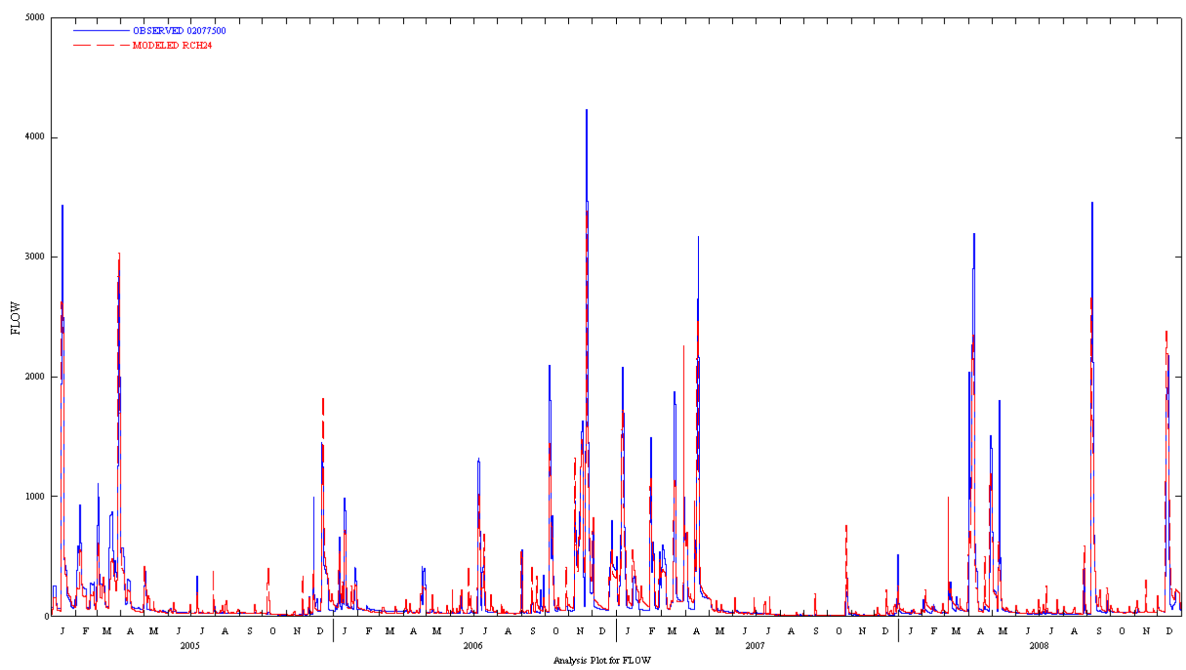


*Figure 3.3 Hyco River HSPF Model Hydrologic Validation Results at USGS Station 02077500*

## 3.3.2 Water Quality Model Setup

The potential sources for fecal coliform production in the Hyco River, Aarons Creek, Little Buffalo Creek, and Beech Creek watersheds were discussed in Chapter 2 - Watershed

Characterization. Although the model results are ultimately used for the development of *E. coli* TMDLs, the HSPF model has been set up for fecal coliform bacteria. The modeled fecal coliform concentrations are converted to *E. coli* concentrations employing the following equation as recommended by VADEQ:

$$\log_2 EC = -0.0172 + 0.91905 * \log_2 FC$$

where, EC = *E. coli* concentration (count/100 mL)
and FC = Fecal coliform bacteria concentration (count/100 mL)

The watershed model has been set up for fecal coliform bacteria because significant data and literature information are available to characterize the accumulation and wash-off of fecal coliform from various nonpoint sources.

#### 3.3.2.1 Nonpoint Sources

In the HSPF model, bacteria loads from nonpoint sources are generally represented by providing appropriate accumulation, decay and wash-off rates from urban sources including pets, agricultural activities and land uses, wildlife sources, and direct deposition from livestock at animal access points to streams. A spreadsheet based template, called the Fecal Tool, was used to compute the accumulation rate and the maximum accumulation per acre, which assumed a first order decay of bacteria depositing on ground.

Bacteria is modeled in the HSPF model as a nonconservative pollutant meaning that bacteria die or decay in the environment. In pervious and impervious land segments bacteria is accumulated on the ground at a user specified rate and the previously accumulated bacteria also decay exponentially (i.e. a first order was used) until a limiting value (the maximum accumulation) is reached. Bacteria accumulated on land surface washes-off to stream reaches during a storm that generates runoff and part of the bacteria population that reach a stream also dies off in the stream. The in-stream decay of bacteria is also modeled using a first order equation.

The pet fecal coliform loading was considered as a land-based load that is primarily deposited in residential areas of a sub-watershed. The daily fecal coliform loading was calculated as the product of the number of pets in the sub-watershed and the daily fecal coliform production per type of pet.

The distribution between direct and indirect loading was determined based on the estimated amount of time that each type of livestock or wildlife spends on the surrounding land areas against the time spent in the stream. The direct fecal coliform load was calculated by multiplying the number of each type of livestock or wildlife in the sub-watershed by the fecal coliform production per animal per day, and by the percentage of time each animal spends in the stream. The indirect (land-based) fecal coliform loading from livestock or wildlife was estimated as the product of the number of each type of animal in the sub-watershed, the fecal coliform production per animal per day, and the percentage of time each animal spends on land within the sub-watershed. The resulting fecal coliform load will then be distributed to appropriate land uses where animals are likely to be present and defecate.

#### *3.3.2.2 Permitted Discharge Facilities*

In absence of continuous monitoring data, average discharge rates were considered as the representative flow for each permitted or non-permitted facility and used for HSPF model set-up and calibration. The bacteria concentrations in the permitted or non-permitted facilities were estimated based on the past monitoring data. For the development of TMDL allocations, all the permitted facilities were considered as constant sources discharging at their design flow and permitted fecal coliform concentrations (i.e. the maximum allowed based on the Water Quality Standards).

#### *3.3.2.3 Failed Septic Systems*

Estimated failed septic systems in the sub-watersheds were represented as either direct or land-based source in the HSPF model, depending on their proximity to the impaired streams. The failure rate of septic tanks was calculated using an average life of septic tanks based on data from the National Small Flow Clearinghouse at the West Virginia University. If a failed septic system was located within a 200-foot stream-buffer, then it was considered as a direct source, otherwise it was assumed as land-based source. In other words the bacteria loads from failed septic systems outside the 200-foot buffer were considered accumulating on land surface and available for wash-off, where as those within the 200-foot buffer were modeled as straight pipes. To calculate the number of failed septic systems, the number of households within a 200-foot stream-buffer was estimated in GIS and then, the number of septic systems was estimated using the percentage of households that use septic systems.

#### *3.3.2.4. Livestock*

Livestock contribution to the total fecal coliform load is generally included within the nonpoint source loads in the model. The only exception is the direct deposition, which is treated similar to point source loads, occurring at animal access points along the streams. Thus, the model accounts for fecal coliform directly deposited in the stream, fecal coliform deposited while livestock are in confinement and later spread onto pasture lands in the watershed, and finally, land-based fecal coliform deposited by livestock while grazing. Based on inventory of livestock in these areas, it was determined that beef cattle are the predominant type of livestock. There are no confined animal feeding operations of beef cattle in the watersheds. Three VPDES permitted animal feeding operations (hog farms) with maximum capacities of 1,216, 2,760, and 2,760 animals are located in Coleman Creek, Little Bluewing Creek, and Aarons Creek sub-watersheds, respectively. Based on discussions with the Technical Advisory Committee, these farms primarily apply manure through irrigation on hay lands only.

Livestock daily schedules determined the distribution of the daily fecal coliform load among direct in-stream and indirect (land-based) loading. Estimations for the direct deposition load from livestock were obtained from livestock numbers in the watershed, the daily fecal coliform production per animal, and the amount of time livestock spent in streams. The amount of livestock in the watershed, the daily fecal coliform per animal, and the percent of time spent in pasture determined the land-based load of fecal coliform from livestock while grazing. Table 3.6 presents the schedule of beef cattle that provided the basis for computing the accumulation rates.

*Table 3.6. Schedule of Beef Cattle Assumed in Estimating Bacteria Accumulation Rates.*

| Month | Time Spent Grazing (hours) | Grazing Time Spent in Streams (hours) |
|---|---|---|
| January | 24.00 | 0.5 |
| February | 24.00 | 0.5 |
| March | 24.00 | 0.75 |
| April | 24.00 | 1.0 |
| May | 24.00 | 1.0 |
| June | 24.00 | 1.25 |
| July | 24.00 | 1.25 |
| August | 24.00 | 1.25 |
| September | 24.00 | 1.0 |
| October | 24.00 | 0.75 |
| November | 24.00 | 0.75 |
| December | 24.00 | 0.5 |

Source: Dodd Creek TMDL Report (VADEQ, 2002)

#### 3.3.2.5 Land Application of Manure

Since beef cattle are the primary livestock present in the Hyco River, Aarons Creek, Little Buffalo Creek, and Beech Creek watersheds, it was assumed that

- Beef cattle spend the majority of their time on pastureland and are not confined.
- Manure generated by beef cattle is applied to pastureland and hay land in the watershed.
- Daily produced manure is treated as an indirect source in the development of the Hyco River, Aarons Creek, Little Buffalo Creek, and Beech Creek watersheds TMDL.

Fecal coliform loading from beef cattle was accounted for via the methods described above.

#### 3.3.2.6 Biosolids

There are no known biosolids applications in the Hyco River, Aarons Creek, Little Buffalo Creek, and Beech Creek watersheds.

#### 3.3.2.7 Wildlife

Fecal loading from wildlife was estimated in a similar way as described in the section above, and indirect and direct fecal coliform contributions were estimated. The indirect/direct distribution was based on estimates of wildlife time spent on the adjacent land versus in the stream.

Daily fecal coliform production per animal and the amount of time wildlife spend instream were added, based on literature values, to the Fecal Tool. Direct fecal coliform was calculated by multiplying fecal coliform production per animal per day by the number of each type of wildlife in the watershed, as well as the percentage of time each animal spends instream. Indirect (land-based) fecal coliform loading was estimated by multiplying the number of each type of wildlife in the watershed, the fecal coliform production per animal per day, and the percent of time each animal spends on land within the watersheds in the scope of this analysis. The resulting fecal coliform load was then divided among different land uses, which represents the most likely areas in the watershed where each type of wildlife would exist and defecate. The indirect fecal coliform load was added to the loads from other sources to estimate to the average unit area loading (cfu/acre/day) by land use and incorporated in the model as accumulation rates.

##### *3.3.2.8 Pets*

For the Hyco River, Aarons Creek, Little Buffalo Creek, and Beech Creek watersheds TMDL, pet fecal coliform loading was considered a land-based load deposited in residential areas of the watershed. The number of pets in the watershed and the daily fecal coliform production per type of pet were multiplied to arrive at the daily fecal coliform loading.

#### 3.3.3 Fecal Coliform Die Off Rates

Fecal coliform decay rates were included in the HSPF model developed for the Hyco River, Aarons Creek, Little Buffalo Creek, and Beech Creek watersheds. The fecal coliform die-off rates required by the model included:

1. On-surface fecal coliform die-off. Fecal coliform undergoes decay prior to being washed into streams, while deposited on land surfaces.
2. In-stream fecal coliform die-off. Fecal coliform will experience decay when directly deposited into the stream and also when entering the stream from indirect sources.

Decay rates of 1.37 and 1.152 per day were used to estimate die-off rates for on-surface and in-stream fecal coliform, respectively (USEPA, 1985).

#### 3.3.4 Water Quality Calibration and Validation

Water quality calibration of the HSPF model involves the adjustment of model parameters to control bacteria accumulation, die-off, wash-off, and transport along with various flow components (e.g. surface runoff, interflow and base flow, and the shape of the hydrographs) and make simulated values match observed flow conditions during the desired calibration period.

Similar to hydrologic calibration, water quality calibration was performed by comparing modeled bacteria concentrations with the observed data. Model calibration is an iterative process in which the model results are compared to the available in-stream data, and the model parameters are adjusted until there is an acceptable agreement between the observed and simulated in-stream concentrations and the build-up and wash-off rates are within the acceptable ranges.

The availability of water quality data is a major factor in determining calibration and validation periods for the model. Model calibration and validation used the water quality station 4AHYC016.70 along Hyco River and the data for the periods January 1, 2009 to December 31, 2012 and January 1, 2005 to December 31, 2008 were used for calibration and validation, respectively.

Modeled fecal coliform concentrations were converted to *E. coli* concentrations prior to making any direct comparison between the two data sets. For the impaired reaches, the modeled *E. coli* concentrations were compared with the observed data from each water quality monitoring station having a substantial number of samples. Figures 3.4 and 3.5 show the time series plots of observed and modeled concentrations for Hyco River for the calibration and validation periods, respectively. Table 3.7 shows the observed and modeled geometric mean and rate of exceedance of the single sample maximum criterion.

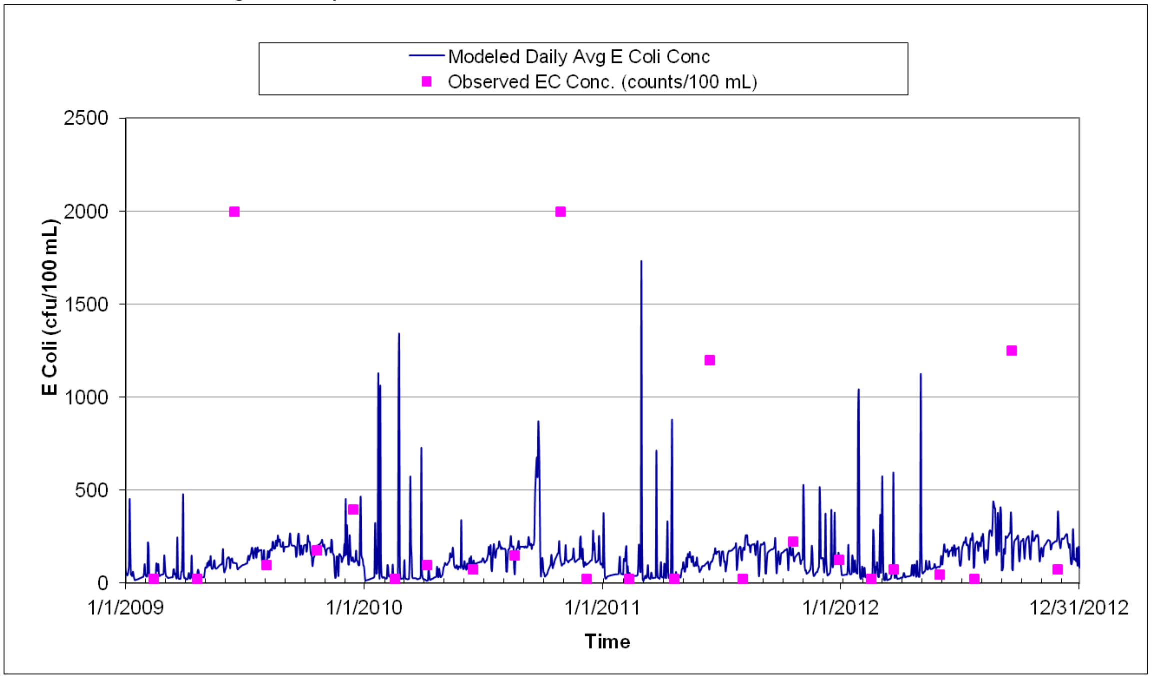


*Figure 3.4. Hyco River Water Quality Calibration (2009-2012) Results at Station 4AHYC016.70.*

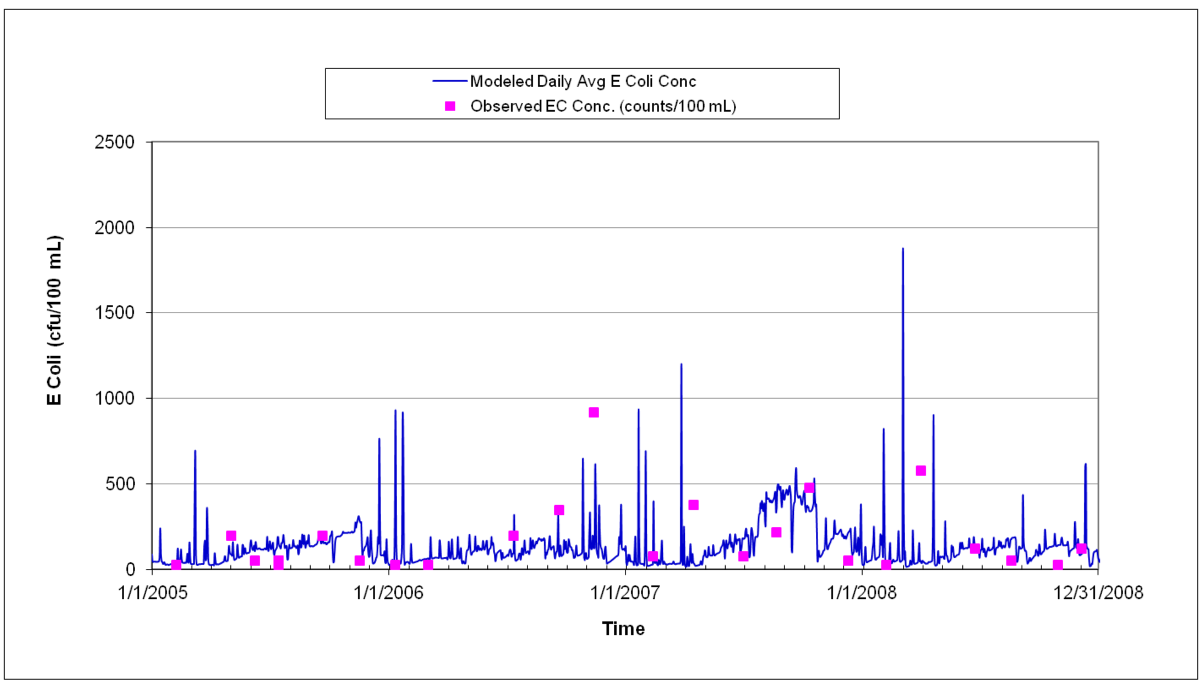


*Figure 3.5. Hyco River Water Quality Validation (2005-2008) Results at Station 4AHYC016.70.*

*Table 3.7. Observed and Simulated Exceedance Rates of the 235 Cfu/100 Ml E. coli Single Sample Maximum Criterion and the Long-Term Geometric Means at Station 4AHYC016.70.*

| Watershed | Model Segment | Rate of Exceedance (>235 cfu/100 mL) | | Geometric Mean | |
|---|---|---|---|---|---|
| | | Simulated | Observed | Simulated | Observed |
| Hyco River | 24 | 0.20 | 0.20 | 98 | 97 |

Figure 3.6 shows the time series plot of observed and modeled concentrations for Aarons Creek for the calibration period only. Very limited water quality data were available for the validation period. Table 3.8 shows the observed and modeled geometric mean and rate of exceedance of the single sample maximum criterion.

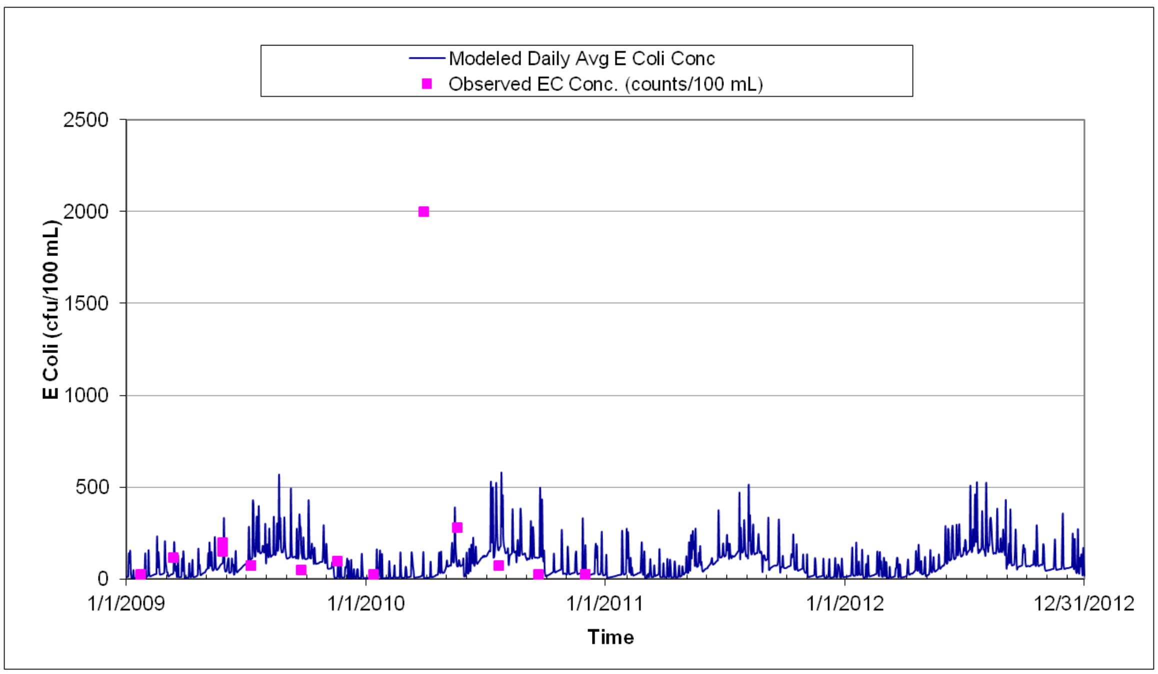


*Figure 3.6. Aarons Creek Water Quality Calibration (2009-2012) Results at Station 4ANFA000.35.*

*Table 3.8. Observed and Simulated Exceedance Rates of the 235 Cfu/100 Ml E coli Single Sample Maximum Criterion and the Long-Term Geometric Means at Station 4ANFA000.35.*

| Watershed | Model Segment | Rate of Exceedance (>235 cfu/100 mL) | | Geometric Mean | |
|---|---|---|---|---|---|
| | | Simulated | Observed | Simulated | Observed |
| Aarons Creek | 3 | 0.17 | 0.12 | 52 | 58 |

Figures 3.7 and 3.8 show the time series plots of observed and modeled concentrations for Beech Creek for the calibration and validation periods, respectively. Table 3.9 shows the

observed and modeled geometric mean and rate of exceedance of the single sample maximum criterion.

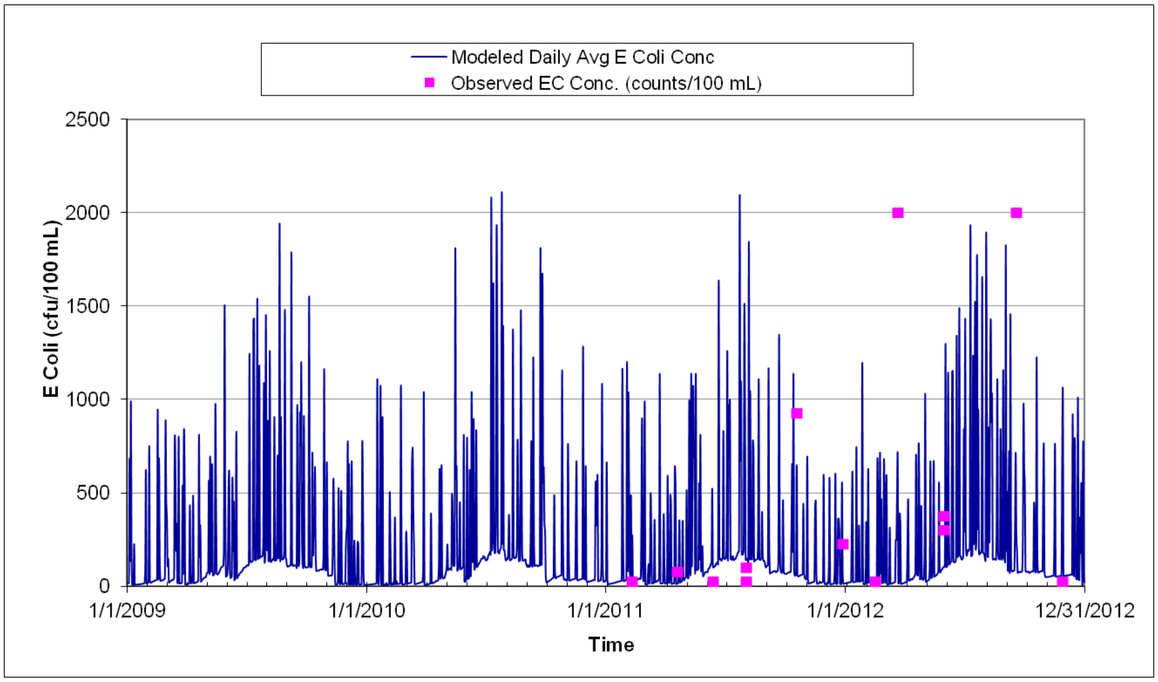


*Figure 3.7. Beech Creek Water Quality Calibration (2009-2012) Results at Station 4ABEE000.80.*

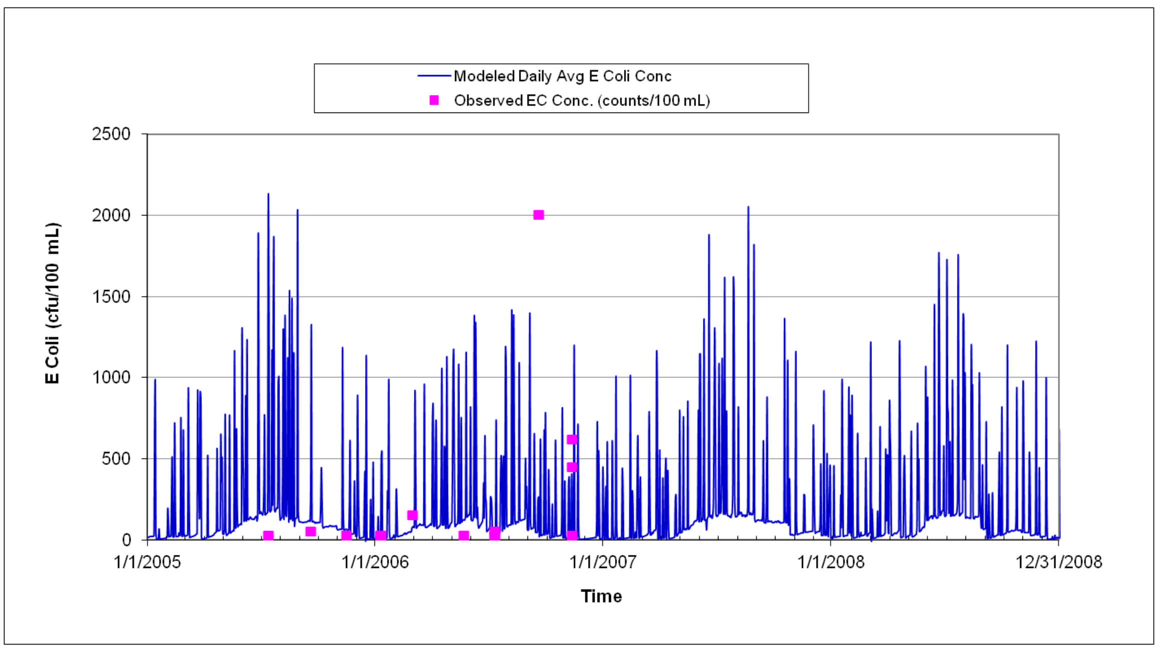


*Figure 3.8. Beech Creek Water Quality Validation (2005-2008) Results at Station 4ABEE000.80.*

*Table 3.9. Observed and Simulated Exceedance Rates of the 235 Cfu/100 Ml E. coli Single Sample Maximum Criterion and the Long-Term Geometric Means at Station 4ABEE000.80.*

| Watershed | Model Segment | Rate of Exceedance (>235 cfu/100 mL) | | Geometric Mean | |
|---|---|---|---|---|---|
| | | Simulated | Observed | Simulated | Observed |
| Beech Creek | 2 | 0.34 | 0.29 | 80 | 90 |

Figure 3.9 shows the time series plot of observed and modeled concentrations for Little Buffalo Creek for the calibration period only. No water quality data were available for the validation period. Table 3.10 shows the observed and modeled geometric mean and rate of exceedance of the single sample maximum criterion.

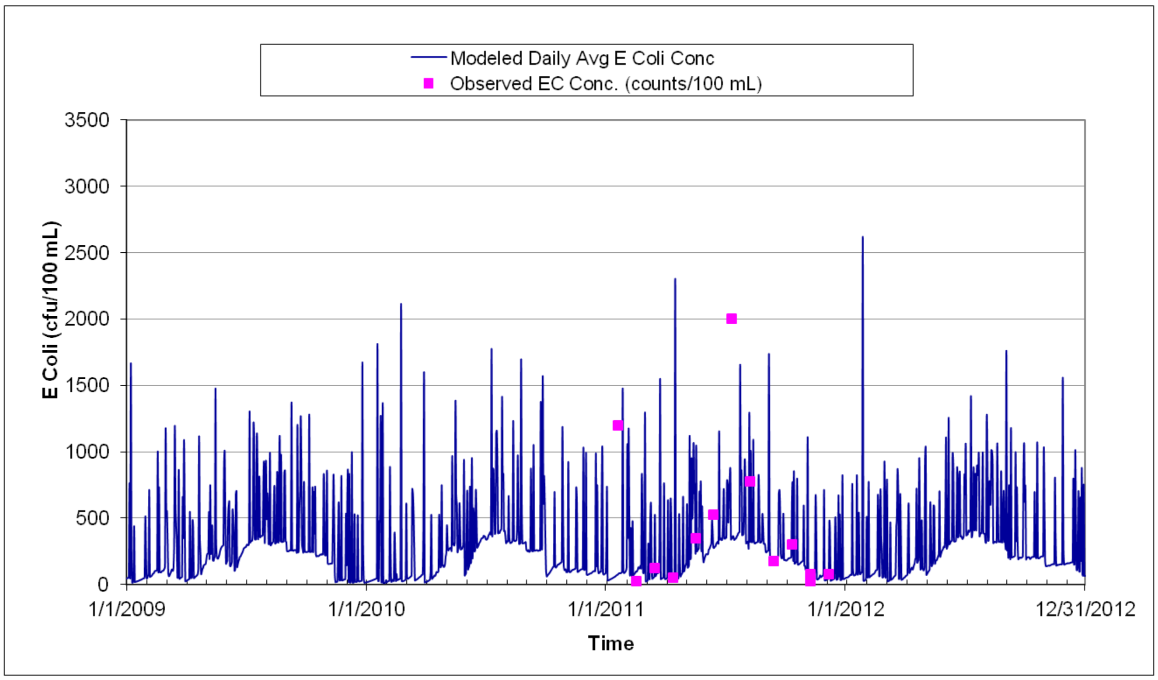


*Figure 3.9. Little Buffalo Creek Water Quality Calibration (2009-2012) Results at Station 4ALFF001.85.*

*Table 3.10. Observed and Simulated Exceedance Rates of the 235 Cfu/100 Ml E. coli Single Sample Maximum Criterion and the Long-Term Geometric Means at Station 4ALFF001.85.*

| Watershed | Model Segment | Rate of Exceedance (>235 cfu/100 mL) | | Geometric Mean | |
|---|---|---|---|---|---|
| | | Simulated | Observed | Simulated | Observed |
| Little Buffalo Creek | 5 | 0.59 | 0.47 | 183 | 200 |

# 4.0 TMDL ALLOCATION

The purpose of the TMDL allocation is to develop the framework for reducing bacteria loading under the existing watershed conditions so that water quality standards can be met. The TMDLs represents the maximum amount of pollutant that the stream can receive without exceeding the water quality criteria. The load allocations for the selected scenarios were calculated using the following equation:

$$TMDL = \Sigma\ WLA + \Sigma\ LA + MOS$$

Where,

WLA = waste load allocation (point source contributions);

LA = load allocation (non-point source contributions); and

MOS = margin of safety.

Typically, several potential allocation strategies would achieve the TMDL endpoint and water quality standards. Available control options depend on the number, location, and character of the pollutant sources.

## 4.1. Incorporation of Margin of Safety

The margin of safety (MOS) is a required component of the TMDL to account for any lack of knowledge concerning the relationship between effluent limitations and water quality. According to EPA guidance (USEPA, 1991), the MOS can be incorporated into the TMDL using one of two methods:

- Implicitly incorporating the MOS using conservative model assumptions to develop allocations.
- Explicitly specifying a portion of the TMDL as the MOS and using the remainder for allocations.

The MOS was implicitly incorporated into this TMDL. Implicitly incorporating the MOS will require that allocation scenarios be designed to meet the monthly geometric mean criterion of 126 cfu/100 mL for *E. coli* bacteria. In addition, it is required that final allocation scenarios be designed so that there is no more than a 10% exceedance rate of the single sample maximum criterion for *E. coli* of 235 cfu/100 mL. Conservative assumptions such as allocating any upstream inputs to the model at the geometric mean and assuming point sources to be operating at design flow and permitted limits (i.e., water quality standard) even though most discharges are well below their design flow and the water quality standard are some examples of an implicit MOS.

## 4.2. Allocation Scenario Development

Allocation scenarios were modeled using the calibrated HSPF model to adjust the existing conditions until the water quality criteria were attained. The Hyco River TMDLs were based on the Virginia water quality criteria for *E. coli*. The *E. coli* criterion states that the calendar-month geometric mean concentration shall not exceed 126 cfu/100 mL, and that a maximum single sample concentration of *E. coli* shall not exceed 235 cfu/100 mL more than 10 percent of the time. According to the guidelines put forth by the VADEQ (VADEQ, 2003) for modeling *E. coli* with HSPF, the model was set up to estimate loads of fecal coliform, and then the model output was converted to concentrations of *E. coli* with the following equation:

$\log_2 EC = -0.0172 + 0.91905 * \log_2 FC$
Where: EC = *E. coli* bacteria concentration (cfu/100 mL)
FC = Fecal coliform bacteria concentration (cfu/100 mL)

The pollutant concentrations were simulated over the entire duration of a representative modeling period, and pollutant loads were adjusted until the criterion was met. The pollutant loads were calculated at the outlet of the impaired segments. The development of the allocation scenarios was an iterative process requiring numerous runs where each run was followed by an assessment of source reduction against the water quality target. The long-term average *E. coli* loads and coefficient of variations were determined to implement the final allocation scenarios and to express the TMDL on a daily basis. Assuming a log-normal distribution of data and a probability of occurrence of 95%, the maximum daily loads were determined using the following equation (USEPA, 2007):

$MDL = LTA \times Exp[z\sigma - 0.5\sigma^2]$
Where: MDL = maximum daily limit (cfu/day)
LTA = long-term average (cfu/day)
z = z statistic of the probability of occurrence
$\sigma^2 = \ln(CV^2 + 1)$
CV = coefficient of variation

Daily expressions for aggregate WLAs and LAs were calculated using the above method. The daily expression of individual WLAs were calculated based on the average annual individual WLAs divided by 365 days in a year. These daily average values are not intended to represent maximum allowable daily loads. Rather, they represent the average daily loadings that may be expected to occur over the long term. The following sections present the waste load allocation (WLA) and load allocation (LA) for the impaired segment.

## 4.3. Wasteload Allocation Development

The allocated *E. coli* load for VPDES facilities permitted to discharge bacteria is based on the actual design flow of the facilities and a maximum *E. coli* concentration of 126 cfu/100 mL. The existing load for general domestic permits is based on the allowable flow rate of 1,000 gallons/day and a maximum *E. coli* concentration of 126 cfu/100 mL. Future growth was accounted for by setting 2% of the TMDL in the watersheds without any point sources. For watersheds with point sources, a growth factor of 2 times the existing load was allocated for future growth.

## 4.4. Load Allocation Development

The reduction of loadings from nonpoint sources, including livestock and wildlife direct deposition, is incorporated into the load allocation. A number of load allocation scenarios were developed in order to determine the final TMDL load allocation. Fecal coliform loading and instream fecal coliform concentrations were estimated for each potential scenario using the HSPF model for the hydrologic period of January 2000 to December 2005. The key load allocation scenarios that were developed to arrive at the final TMDL allocations are the combinations of reductions from human source (failed septic systems and straight pipes), reductions from direct deposition from cattle, reductions from pasture/hay non-point sources, reductions from developed land use non-point sources and reductions from direct deposition from wildlife. It should be noted that these key scenarios were developed for all segments. However, additional scenarios were also developed when deemed necessary to attain the final TMDL.

### 4.4.1 Hyco River (VAC-L74R_HYC01A00 and VAC-L74R_HYC02A06)

This section presents the wasteload and load allocation plan and TMDL summary for the Hyco River impaired segments. The allocation scenarios are developed for Hyco River and all the impaired segments within the watershed. The impaired segments in addition to Hyco River (VAC-L74R_HYC01A00 and VAC-L74R_HYC02A06) include Big Bluewing Creek (VAC-L74R_BLU01A08), Coleman Creek (VAC-L74R_CLB01A06), and Little Coleman Creek (VAC-L74R_LOL01A06).

#### *4.4.1.1 Hyco River Wasteload Allocation*

There are two permitted facilities and a number of domestic-sewage facilities discharging bacteria to the Hyco River watershed. The DMR data provided showed a very small flow from the two facilities with no bacterial concentration reported. For the allocation scenarios, the facilities were assumed to discharge at the design flow limits and bacterial concentrations at the existing *E. coli* standard of 126 cfu/100 mL. Table 4.1 shows the existing and allocated loads of dischargers in Hyco River (Segment VAC-L74R_HYC01A00).

*Table 4.1. Wasteload Allocations for Hyco River Watershed.*

| Permit Number | Facility Name | Existing Load (cfu/year) | Allocated Load (cfu/year) |
|---|---|---|---|
| VA0091804 | Halifax County Schools-Cluster Springs Elem | 2.09E+10 | 2.09E+10 |
| VA0022691 | South Boston Foursquare Church | 1.46E+10 | 1.46E+10 |
| VAG407293 | Domestic Sewage | 1.74E+09 | 1.74E+09 |
| VAG404089 | Domestic Sewage | 1.74E+09 | 1.74E+09 |
| VAG407242 | Domestic Sewage | 1.74E+09 | 1.74E+09 |
| VAG407241 | Domestic Sewage | 1.74E+09 | 1.74E+09 |
| VAG407238 | Domestic Sewage | 1.74E+09 | 1.74E+09 |
| VAG404179 | Domestic Sewage | 1.74E+09 | 1.74E+09 |
| VAG404045 | Domestic Sewage | 1.74E+09 | 1.74E+09 |

| Permit Number | Facility Name | Existing Load (cfu/year) | Allocated Load (cfu/year) |
|---|---|---|---|
| VAG407229 | Domestic Sewage | 1.74E+09 | 1.74E+09 |
| VAG407257 | Domestic Sewage | 1.74E+09 | 1.74E+09 |
| VAG407339 | Domestic Sewage | 1.74E+09 | 1.74E+09 |
| VAG404014 | Domestic Sewage | 1.74E+09 | 1.74E+09 |
| VAG407239 | Domestic Sewage | 1.74E+09 | 1.74E+09 |
| VAG404044 | Domestic Sewage | 1.74E+09 | 1.74E+09 |
| | Future Growth | | 2.66E+12 |
| | Total | 5.81E+10 | 2.72E+12 |

#### 4.4.1.2 Hyco River Load Allocation Plan and TMDL Summary

The requirements to meet the calendar month *E. coli* geometric mean water quality standard of 126 cfu/100 mL and the single sample maximum criterion of 235 cfu/100 mL for the Hyco River impaired segment (VAC-L74R_HYC01A00) are:

- 100% reduction of the human sources (failed septic systems and straight pipes)
- 99% reduction of the direct livestock instream loading
- 60% reduction of bacteria loading from pasture and hay nonpoint sources
- 50% reduction of bacterial loading from urban nonpoint sources
- No reduction of bacteria loading from direct deposition from wildlife
- No reductions from the forested land (wildlife indirect loads)

The estimated load reductions and percent exceedances under each allocation modeling scenario for the Hyco River impaired segment are presented in Table 4.2. Table 4.3 details the existing loads, allocated loads, and percent reductions to meet the allocations for each land use/source in the Hyco River TMDL watershed.

*Table 4.2. Load Allocation Scenario Results for Hyco River Watershed.*

| | Percent Reductions to Existing Bacterial Loads | | | | | VADEQ *E. coli* Standard percent violations | |
|---|---|---|---|---|---|---|---|
| Scenario | Human Sources[2] | Direct Deposition from Cattle | Non-Point Source - Pasture | Non-point Source - Developed Land uses | Direct Deposition from Wildlife | % > 126 GM | % > 235 cfu/100mL[1] |
| 0 | | | | | | 5.2 | 6.6 |
| 1 | 100 | | | | | 5.2 | 6.6 |
| 2 | 100 | 100 | | | | 1.0 | 6.2 |
| 3 | 100 | 100 | | | 100 | 1.0 | 5.7 |
| 4 | 100 | 100 | 50 | | | 0.0 | 4.7 |
| 5 | 100 | 100 | | 50 | | 1.0 | 5.3 |

| Scenario | Percent Reductions to Existing Bacterial Loads | | | | | VADEQ *E. coli* Standard percent violations | |
|---|---|---|---|---|---|---|---|
| | Human Sources[2] | Direct Deposition from Cattle | Non-Point Source - Pasture | Non-point Source - Developed Land uses | Direct Deposition from Wildlife | % > 126 GM | % > 235 cfu/100mL[1] |
| 6[3] | 100 | 99 | 60 | 50 | | 0.0 | 3.8 |
| 7 | 100 | 99 | 55 | 50 | 20 | 0.0 | 3.9 |

[1]Human sources are failed septic systems and straight pipes
[1]The235 cfu/100 mL single sample maximum criteria allows up to 10% exceedance
[3] Final TMDL Scenario.

***Table 4.3. Annual Average E. coli Load under Existing Conditions and TMDL Allocation for Hyco River.***

| Bacterial Source | Annual Average *E. coli* Loads (cfu/year) | | Reduction % |
|---|---|---|---|
| | Existing Condition | Allocation | |
| Developed Urban | 2.61E+13 | 1.31E+13 | 50 |
| Crop | 1.15E+10 | 1.15E+10 | 0 |
| Forest | 1.55E+12 | 1.55E+12 | 0 |
| High Residential | 4.27E+11 | 2.14E+11 | 50 |
| Medium Residential | 8.31E+11 | 4.16E+11 | 50 |
| Low Residential | 2.03E+12 | 1.02E+12 | 50 |
| Pasture and Hay | 2.52E+14 | 1.01E+14 | 60 |
| Wetland | 8.99E+12 | 8.99E+12 | 0 |
| Barren Land | 1.35E+12 | 1.35E+12 | 0 |
| Point Sources | 5.81E+10 | 5.81E+10 | 0 |
| Direct Deposition from Cattle | 1.10E+13 | 1.10E+11 | 99 |
| Direct Deposition from Wildlife | 5.11E+12 | 5.11E+12 | 0 |
| Human Sources[1] | 2.22E+11 | 0.00E+00 | 100 |
| Future Growth | 0.00E+00 | 2.66E+12 | |
| Total | 3.13E+14 | 1.36E+14 | 56.7% |

[1]Human sources are failed septic systems and straight pipes

Summaries of the TMDL for the Hyco River are presented in Tables 4.4 and 4.5. The developed TMDL meets the geometric standard and single sample maximum criterion for the impaired segments of the Hyco River (VAC-L74R_HYC01A00 and VAC-L74R_HYC02A06), Big Bluewing Creek (VAC-L74R_BLU01A08), Coleman Creek (VAC-L74R_CLB01A06), and Little Coleman Creek (VAC-L74R_LOL01A06).

Table 4.4. Hyco River TMDL (cfu/year) for E. coli.

| Impairment | WLA[1] | LA | MOS | TMDL | Existing Load | Percent Reduction |
|---|---|---|---|---|---|---|
| Hyco River (VAC-L74R_HYC01A00, VAC-L74R_HYC02A06) Big Bluewing Creek (VAC-L74R_BLU01A08) Coleman Creek (VAC-L74R_CLB01A06) Little Coleman Creek (VAC-L74R_LOL01A06) | 2.72E+12 | 1.33E+14 | Implicit | 1.36E+14 | 3.13E+14 | 56.7% |
| VA0091804[1] | 2.09E+10 | | | | | |
| VA0022691[1] | 1.46E+10 | | | | | |
| VAG407293[1] | 1.74E+09 | | | | | |
| VAG404089[1] | 1.74E+09 | | | | | |
| VAG407242[1] | 1.74E+09 | | | | | |
| VAG407241[1] | 1.74E+09 | | | | | |
| VAG407238[1] | 1.74E+09 | | | | | |
| VAG404179[1] | 1.74E+09 | | | | | |
| VAG404045[1] | 1.74E+09 | | | | | |
| VAG407229[1] | 1.74E+09 | | | | | |
| VAG407257[1] | 1.74E+09 | | | | | |
| VAG407339[1] | 1.74E+09 | | | | | |
| VAG404014[1] | 1.74E+09 | | | | | |
| VAG407239[1] | 1.74E+09 | | | | | |
| VAG404044[1] | 1.74E+09 | | | | | |
| Future Growth[2] | 2.66E+12 | | | | | |

[1]Any issued permit will include bacteria effluent limits in accordance with applicable permit guidance and will ensure the discharge meets the applicable numeric water quality criteria for bacteria at the end-of-pipe.
[2]The WLA reflects an allocation for potential future permits issued for bacteria control.

Table 4.5. Hyco River TMDL (cfu/day) for E. coli.

| Impairment | WLA[1] | LA | MOS | TMDL | Existing Load | Percent Reduction |
|---|---|---|---|---|---|---|
| Hyco River (VAC-L74R_HYC01A00, VAC-L74R_HYC02A06) Big Bluewing Creek (VAC-L74R_BLU01A08) Coleman Creek (VAC-L74R_CLB01A06) Little Coleman Creek (VAC-L74R_LOL01A06) | 2.78E+10 | 1.36E+12 | Implicit | 1.39E+12 | 3.17E+12 | 56.3% |
| VA0091804[1] | 2.14E+08 | | | | | |
| VA0022691[1] | 1.50E+08 | | | | | |
| VAG407293[1] | 1.78E+07 | | | | | |

| Impairment | WLA[1] | LA | MOS | TMDL | Existing Load | Percent Reduction |
|---|---|---|---|---|---|---|
| VAG404089[1] | 1.78E+07 | | | | | |
| VAG407242[1] | 1.78E+07 | | | | | |
| VAG407241[1] | 1.78E+07 | | | | | |
| VAG407238[1] | 1.78E+07 | | | | | |
| VAG404179[1] | 1.78E+07 | | | | | |
| VAG404045[1] | 1.78E+07 | | | | | |
| VAG407229[1] | 1.78E+07 | | | | | |
| VAG407257[1] | 1.78E+07 | | | | | |
| VAG407339[1] | 1.78E+07 | | | | | |
| VAG404014[1] | 1.78E+07 | | | | | |
| VAG407239[1] | 1.78E+07 | | | | | |
| VAG404044[1] | 1.78E+07 | | | | | |
| Future Growth[2] | 2.72E+10 | | | | | |

[1]Any issued permit will include bacteria effluent limits in accordance with applicable permit guidance and will ensure the discharge meets the applicable numeric water quality criteria for bacteria at the end-of-pipe.
[2]The WLA reflects an allocation for potential future permits issued for bacteria control.

The resulting geometric mean and single sample maximum *E. coli* concentrations under the TMDL allocation plan are presented in Figure 4.1 and Figure 4.2. Figure 4.1 shows the calendar month geometric mean *E. coli* concentrations for existing and allocation conditions. Figure 4.2 shows the single sample maximum *E. coli* concentrations under existing and allocations conditions.

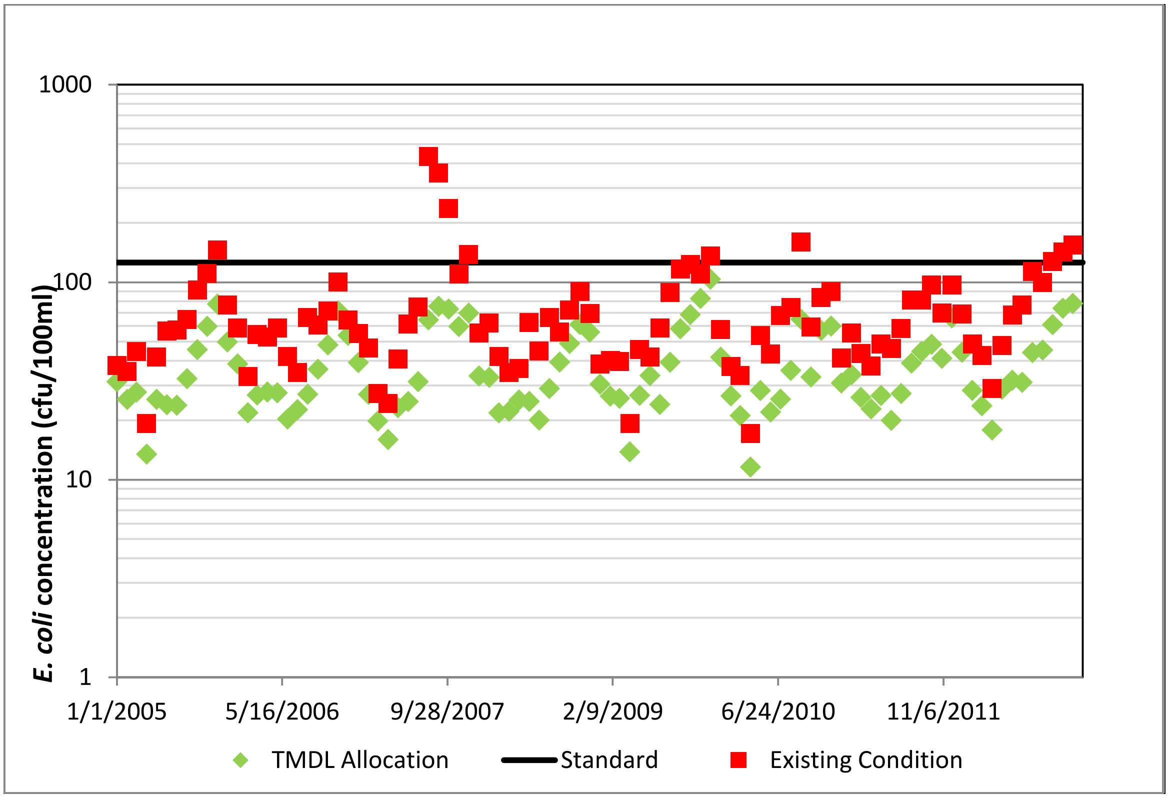


*Figure 4.1. Hyco River Geometric Mean E. coli Concentrations under Existing and TMDL Conditions.*

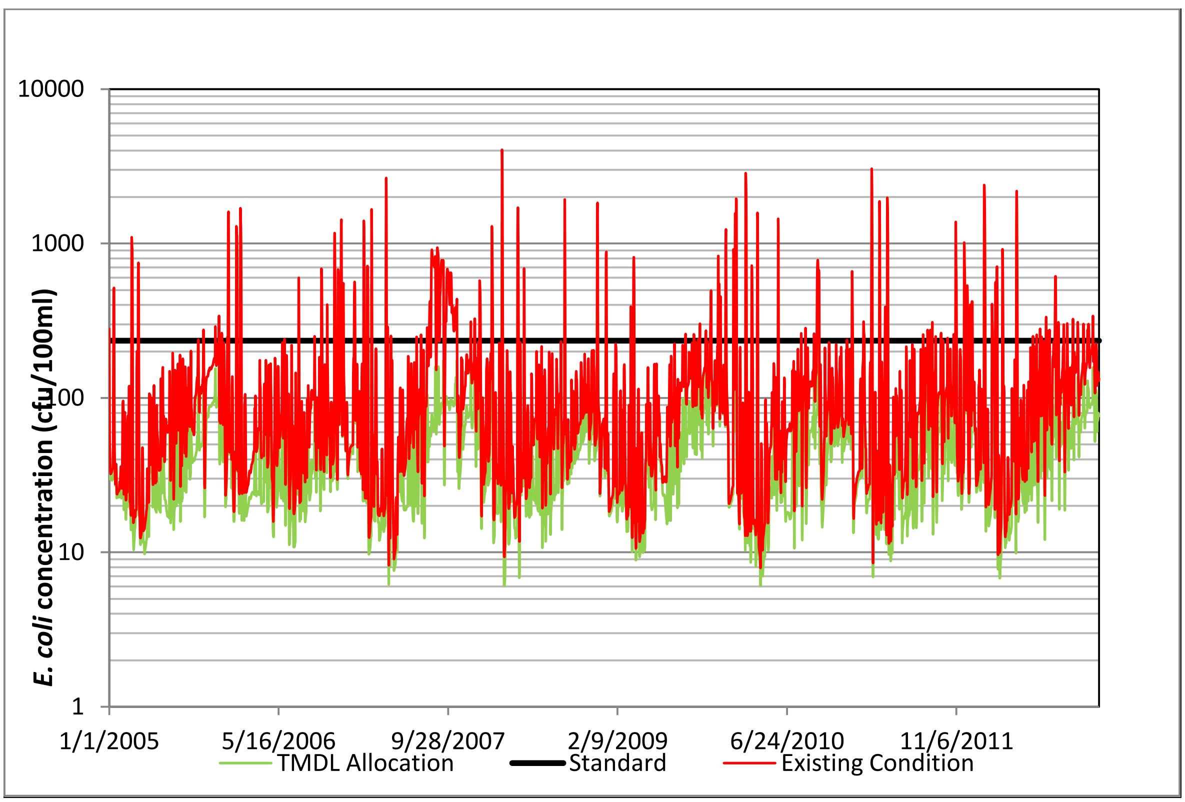


*Figure 4.2. Hyco River Single Sample Maximum E. coli Concentrations under Existing and TMDL Conditions.*

4.4.2 Aarons Creek (VAC-L73R_AAR01A00)

This section presents the wasteload and load allocation plan and TMDL summary for the Aarons Creek impaired segments. The allocation scenarios are developed for Aarons Creek (Segment VAC-L73R_AAR01A00) and North Fork Aarons Creek (Segment VAC-L73R_NFA01A06).

### 4.4.2.1 Aarons Creek Wasteload Allocation

There is a single permitted facility and number of domestic-sewage facilities discharging bacteria to the Aarons Creek watershed. The DMR data provided showed only very small flow from VA0076830 and showed no bacterial concentration reported. For the allocation scenarios, the facilities were assumed to discharge at the design flow limits and bacterial concentrations at the existing *E. coli* standard of 126 cfu/100 mL. Table 4.6 shows the existing and allocated loads of dischargers in Aarons Creek.

**Table 4.6. Wasteload Allocations for Aarons Creek Watershed.**

| Permit Number | Facility Name | Existing Load (cfu/year) | Allocated Load (cfu/year) |
|---|---|---|---|
| VA0076830 | Virgilina, Town of | 6.09E+10 | 6.09E+10 |
| VAG407266 | Domestic Sewage | 1.74E+09 | 1.74E+09 |
| VAG407249 | Domestic Sewage | 1.74E+09 | 1.74E+09 |
| VAG407236 | Domestic Sewage | 1.74E+09 | 1.74E+09 |
| VAG404093 | Domestic Sewage | 1.74E+09 | 1.74E+09 |
| VAG407206 | Domestic Sewage | 1.74E+09 | 1.74E+09 |
| VAG404024 | Domestic Sewage | 1.74E+09 | 1.74E+09 |
| VAG407255 | Domestic Sewage | 1.74E+09 | 1.74E+09 |
| VAG404011 | Domestic Sewage | 1.74E+09 | 1.74E+09 |
| VAG407351 | Domestic Sewage | 1.74E+09 | 1.74E+09 |
| | Future Growth | 0 | 2.80E+11 |
| | Total | 7.66E+10 | 3.57E+11 |

### 4.4.2.2 Aarons Creek Load Allocation Plan and TMDL Summary

The requirements to meet the calendar month *E. coli* geometric mean water quality standard of 126 cfu/100 mL and the single sample maximum criterion of 235 cfu/100 mL for the Aarons Creek impaired segment are:

- 100% reduction of the human sources (failed septic systems and straight pipes)
- 95% reduction of the direct livestock instream loading
- 40% reduction of bacteria loading from pasture and hay nonpoint sources
- 30% reduction of bacterial loading from urban nonpoint sources
- No reduction of bacteria loading from direct deposition from wildlife
- No reductions from the forested land (wildlife indirect loads)

The estimated load reductions and percent exceedances under each allocation modeling scenario for the Aarons Creek impaired segment is presented in Table 4.7. Table 4.8 details the existing loads, allocated loads, and percent reductions to meet the allocations for each land use/source in the Aarons Creek TMDL watershed.

*Table 4.7. Load Allocation Scenario Results for Aarons Creek Watershed.*

| Scenario | Percent Reductions to Existing Bacterial Loads | | | | | VADEQ *E. coli* Standard percent violations | |
|---|---|---|---|---|---|---|---|
| | Human Sources[2] | Direct Deposition from Cattle | Non-Point Source - Pasture | Non-point Source - Developed Land uses | Direct Deposition from Wildlife | % > 126 GM | % > 235 cfu/100mL[2] |
| 0 | | | | | | 24.0 | 15.1 |
| 1 | 100 | | | | | 24.0 | 14.7 |
| 2 | 100 | 100 | | | | 1.0 | 7.1 |
| 3 | 100 | | | | 100 | 22.9 | 13.8 |
| 4 | 100 | 100 | 50 | | | 0.0 | 5.3 |
| 5 | 100 | 100 | | 50 | | 0.0 | 4.3 |
| 6 | 100 | 100 | 10 | 10 | | 0.0 | 6.2 |
| 7[3] | 100 | 95 | 40 | 30 | | 0.0 | 4.1 |
| 8 | 100 | 95 | 35 | 30 | 20 | 0.0 | 4.3 |

[1]Human sources are failed septic systems and straight pipes
[2]The235 cfu/100mL single sample maximum criteria allows up to 10% exceedance
[3]Final TMDL Scenario

*Table 4.8. Annual Average E. coli Load under Existing Conditions and TMDL Allocation for Aarons Creek.*

| Bacterial Source | Average Annual *E. coli* loads (cfu/year) | | Reduction % |
|---|---|---|---|
| | Existing Condition | Allocation | |
| Developed Urban | 4.57E+12 | 3.20E+12 | 30 |
| Crop | 6.61E+09 | 6.61E+09 | 0 |
| Forest | 7.08E+11 | 7.08E+11 | 0 |
| Medium Residential | 1.69E+11 | 1.18E+11 | 30 |
| Low Residential | 5.14E+11 | 5.14E+11 | 0 |
| Pasture and Hay | 8.60E+12 | 5.16E+12 | 40 |
| Wetland | 3.80E+12 | 3.80E+12 | 0 |
| Barren Land | 2.99E+09 | 2.99E+09 | 0 |
| Point Sources | 7.66E+10 | 7.66E+10 | 0 |
| Direct Deposition from Cattle | 3.24E+12 | 1.62E+11 | 95 |
| Direct Deposition from Wildlife | 2.63E+11 | 2.63E+11 | 0 |
| Human Sources[1] | 1.13E+11 | 0.00E+00 | 100 |
| Future Growth | 0.00E+00 | 2.80E+11 | |
| Total | 2.21E+13 | 1.43E+13 | 35.2% |

[1]Human sources are failed septic systems and straight pipes

Summaries of the TMDL for Aarons Creek are presented in Tables 4.9 and 4.10. The developed TMDL meets the geometric standard and single sample maximum criterion for the impaired segments of Aarons Creek (VAC-L73R_AAR01A00), and North Fork Aarons Creek (VAC-L73R_NFA01A06).

***Table 4.9. Aarons Creek TMDL (cfu/year) for E. coli.***

| Impairment | WLA[1] | LA | MOS | TMDL | Existing Load | Percent Reduction |
|---|---|---|---|---|---|---|
| Aarons Creek (VAC-L73R_AAR01A00) North Fork Aarons Creek (VAC-L73R_NFA01A06) | 3.57E+11 | 1.39E+13 | Implicit | 1.43E+13 | 2.21E+13 | 35.2% |
| VA0076830[1] | 6.09E+10 | | | | | |
| VAG407266[1] | 1.74E+09 | | | | | |
| VAG407249[1] | 1.74E+09 | | | | | |
| VAG407236[1] | 1.74E+09 | | | | | |
| VAG404093[1] | 1.74E+09 | | | | | |
| VAG407206[1] | 1.74E+09 | | | | | |
| VAG404024[1] | 1.74E+09 | | | | | |
| VAG407255[1] | 1.74E+09 | | | | | |
| VAG404011[1] | 1.74E+09 | | | | | |
| VAG407351[1] | 1.74E+09 | | | | | |
| Future Growth[2] | 2.80E+11 | | | | | |

[1]Any issued permit will include bacteria effluent limits in accordance with applicable permit guidance and will ensure the discharge meets the applicable numeric water quality criteria for bacteria at the end-of-pipe.
[2]The WLA reflects an allocation for potential future permits issued for bacteria control.

***Table 4.10. Aarons Creek TMDL (cfu/day) for E. coli.***

| Impairment | WLA[1] | LA | MOS | TMDL | Existing Load | Percent Reduction |
|---|---|---|---|---|---|---|
| Aarons Creek (VAC-L73R_AAR01A00) North Fork Aarons Creek (VAC-L73R_NFA01A06) | 3.77E+09 | 1.47E+11 | Implicit | 1.51E+11 | 2.33E+11 | 35.2% |
| VA0076830[1] | 6.45E+08 | | | | | |
| VAG407266[1] | 1.84E+07 | | | | | |
| VAG407249[1] | 1.84E+07 | | | | | |
| VAG407236[1] | 1.84E+07 | | | | | |
| VAG404093[1] | 1.84E+07 | | | | | |
| VAG407206[1] | 1.84E+07 | | | | | |
| VAG404024[1] | 1.84E+07 | | | | | |
| VAG407255[1] | 1.84E+07 | | | | | |
| VAG404011[1] | 1.84E+07 | | | | | |

| | | | | | | |
|---|---|---|---|---|---|---|
| VAG407351[1] | 1.84E+07 | | | | | |
| Future Growth[2] | 2.96E+09 | | | | | |

[1]Any issued permit will include bacteria effluent limits in accordance with applicable permit guidance and will ensure the discharge meets the applicable numeric water quality criteria for bacteria at the end-of-pipe.
[2]The WLA reflects an allocation for potential future permits issued for bacteria control.

The resulting geometric mean and single sample maximum *E. coli* concentrations under the TMDL allocation plan are presented in Figure 4.3 and Figure 4.4. Figure 4.3 shows the calendar month geometric mean *E. coli* concentrations for existing as well as under the allocation conditions. Figure 4.4 shows the single sample maximum *E. coli* concentrations under the allocations, as well as under existing conditions.

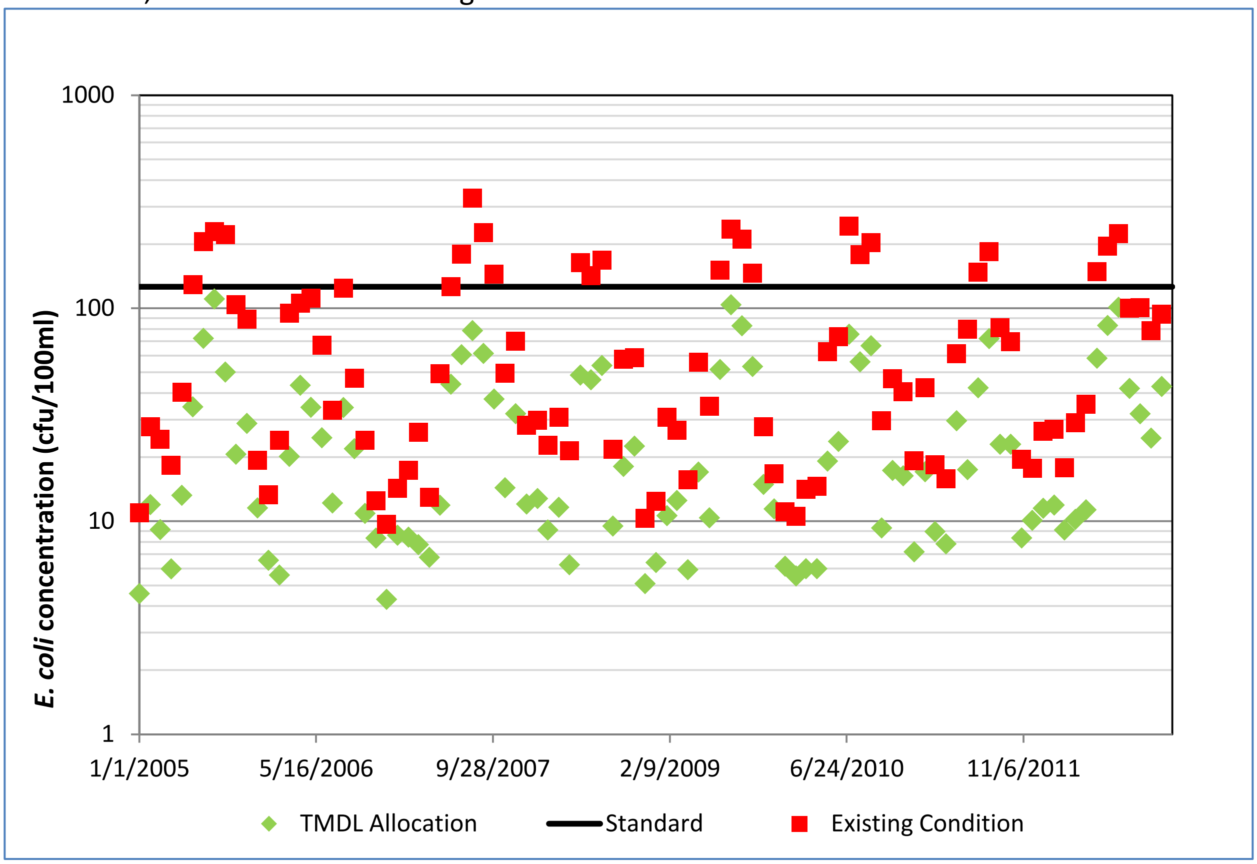


*Figure 4.3. Aarons Creek Geometric Mean E. coli Concentrations under Existing and TMDL Conditions.*

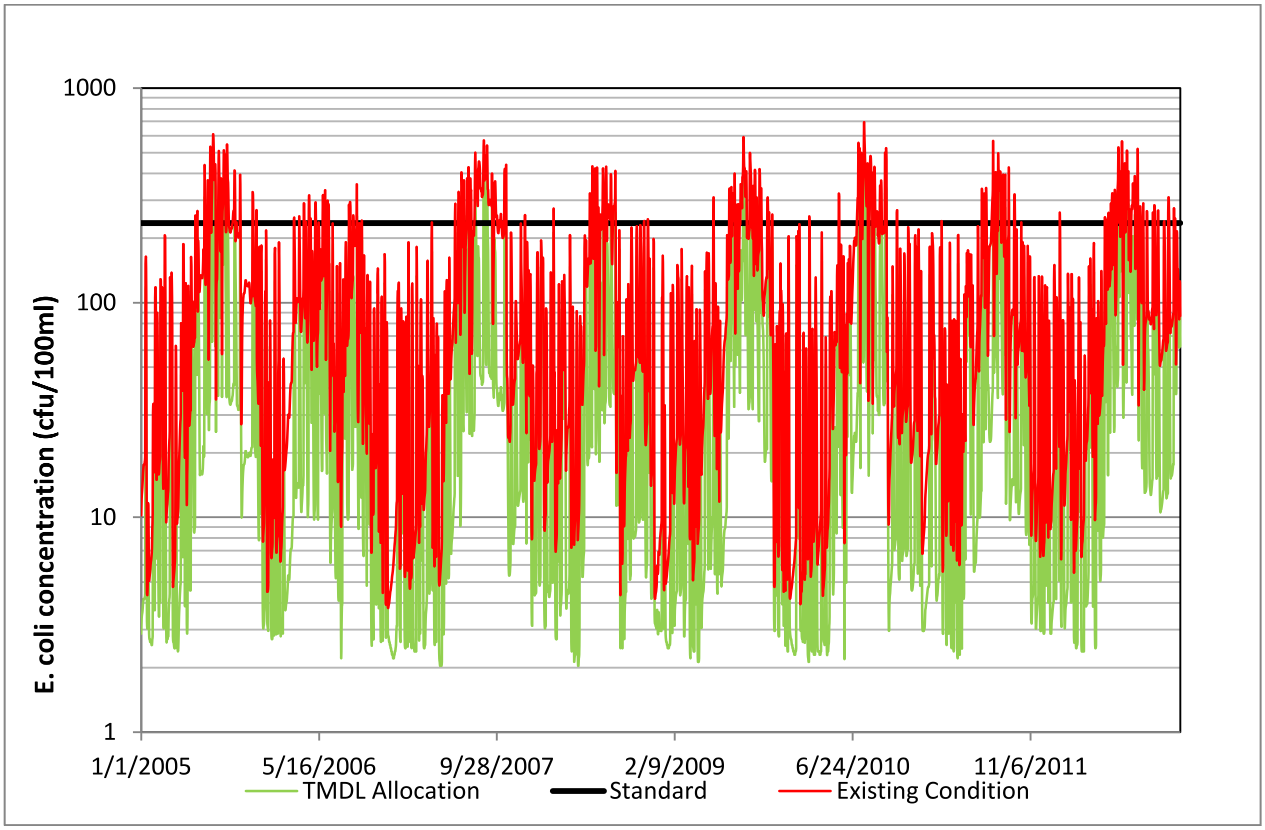


*Figure 4.4. Aarons Creek Single Sample Maximum E. coli Concentrations under Existing and TMDL Conditions.*

4.4.3 Beech Creek (VAC-L75R_BEE01A98)

This section presents the wasteload and load allocation plan and TMDL summary for the Beech Creek impaired segments.

#### *4.4.3.1 Beech Creek Wasteload Allocation*

There is a single domestic-sewage facility that is discharging bacteria to the Beech Creek watershed. For the allocation scenarios, the facility was assumed to discharge at the design flow limit of 1,000 GPD and bacterial concentrations at the existing *E. coli* standard of 126 cfu/100mL. Table 4.11 shows the existing and allocated loads of dischargers in Beech Creek.

*Table 4.11. Wasteload Allocations for Beech Creek Watershed.*

| Permit Number | Facility Name | Existing Load (cfu/year) | Allocated Load (cfu/year) |
|---|---|---|---|
| VAG407314 | Domestic Sewage | 1.74E+09 | 1.74E+09 |
| | Future Growth | 0 | 4.88E+10 |
| | Total | 1.74E+09 | 5.06E+10 |

### 4.4.3.2 Beech Creek Load Allocation Plan and TMDL Summary

The requirements to meet the calendar month *E. coli* geometric mean water quality standard of 126 cfu/100 mL and the single sample maximum criterion of 235 cfu/100 mL for the Beech Creek impaired segment are:

- 100% reduction of the human sources (failed septic systems and straight pipes)
- 99% reduction of the direct livestock instream loading
- 90% reduction of bacteria loading from pasture and hay nonpoint sources
- 90% reduction of bacterial loading from urban nonpoint sources
- 30% reduction of bacteria loading from direct deposition from wildlife
- No reductions from the forested land (wildlife indirect loads)

The estimated load reductions and percent exceedances under each allocation modeling scenario for the Beech Creek impaired segment is presented in Table 4.12. Table 4.13 details the existing loads, allocated loads, and percent reductions to meet the allocations for each land use/source in the Beech Creek TMDL watershed.

*Table 4.12. Load Allocation Scenario Results for Beech Creek Watershed.*

| Scenario | Percent Reductions to Existing Bacterial Loads | | | | | VADEQ *E. coli* Standard percent violations | |
|---|---|---|---|---|---|---|---|
| | Human Sources[1] | Direct Deposition from Cattle | Non-Point Source - Pasture | Non-point Source - Developed Land uses | Direct Deposition from Wildlife | % > 126 GM | % > 235 cfu/100mL[2] |
| 0 | | | | | | 34.4 | 35.9 |
| 1 | 100 | | | | | 34.4 | 35.3 |
| 2 | 100 | 100 | | | | 0.0 | 26.7 |
| 3 | 100 | | | | 100 | 32.3 | 34.3 |
| 4 | 100 | 100 | 90 | | | 0.0 | 17.6 |
| 5 | 100 | 100 | 90 | 90 | | 0.0 | 11.1 |
| 6 | 100 | 99 | 91 | 96 | | 0.0 | 9.9 |
| 7[3] | 100 | 99 | 90 | 90 | 30 | 0.0 | 9.3 |

[1]Human sources are failed septic systems and straight pipes
[1]The235 cfu/100mL single sample maximum criteria allows up to 10% exceedance
[2] Final TMDL Scenario.

*Table 4.13. Annual Average E. coli Load under Existing Conditions and TMDL Allocation for Beech Creek.*

| Bacterial Source | Annual Average *E. coli* Loads (cfu/year) | | Reduction % |
|---|---|---|---|
| | Existing Condition | Allocation | |
| Developed Urban | 8.12E+11 | 8.12E+10 | 90 |
| Crop | 2.86E+09 | 2.86E+09 | 0 |
| Forest | 9.89E+10 | 9.89E+10 | 0 |
| Low Residential | 9.09E+10 | 9.09E+09 | 90 |
| Pasture and Hay | 1.58E+13 | 1.58E+12 | 90 |
| Wetland | 6.01E+11 | 6.01E+11 | 0 |

| | | | |
|---|---|---|---|
| Barren Land | 1.57E+10 | 1.57E+10 | 0 |
| Point Sources | 1.74E+09 | 1.74E+09 | 0 |
| Direct Deposition from Cattle | 6.75E+11 | 6.75E+09 | 99 |
| Direct Deposition from Wildlife | 5.46E+10 | 3.82E+10 | 30 |
| Human Sources[1] | 5.46E+10 | 0.00E+00 | 100 |
| Future Growth | | 4.88E+10 | |
| Total | 1.83E+13 | 2.49E+12 | 86.4% |

[1]Human sources are failed septic systems and straight pipes

Summaries of the TMDLs for Beech Creek are presented in Tables 4.14 and 4.15. The developed TMDL meets the geometric standard and single sample maximum criterion for the impaired segment of Beech Creek (VAC-L75R_BEE01A98).

**Table 4.14 Beech Creek TMDL (cfu/year) for *E. coli***

| Impairment | WLA[1] | LA | MOS | TMDL | Existing Load | Percent Reduction |
|---|---|---|---|---|---|---|
| Beech Creek (VAC-L75R_BEE01A98) | 5.06E+10 | 2.44E+12 | Implicit | 2.49E+12 | 1.83E+13 | 86.4% |
| VAG407314[1] | 1.74E+09 | | | | | |
| Future Growth[2] | 4.88E+10 | | | | | |

[1]Any issued permit will include bacteria effluent limits in accordance with applicable permit guidance and will ensure the discharge meets the applicable numeric water quality criteria for bacteria at the end-of-pipe.
[2]The WLA reflects an allocation for potential future permits issued for bacteria control.

**Table 4.15 Beech Creek TMDL (cfu/day) for *E. coli***

| Impairment | WLA[1] | LA | MOS | TMDL | Existing Load | Percent Reduction |
|---|---|---|---|---|---|---|
| Beech Creek (VAC-L75R_BEE01A98) | 4.55E+08 | 2.20E+10 | Implicit | 2.24E+10 | 1.64E+11 | 86.4% |
| VAG407314[1] | 1.57E+07 | | | | | |
| Future Growth[2] | 4.40E+08 | | | | | |

[1]Any issued permit will include bacteria effluent limits in accordance with applicable permit guidance and will ensure the discharge meets the applicable numeric water quality criteria for bacteria at the end-of-pipe.
[2]The WLA reflects an allocation for potential future permits issued for bacteria control.

The resulting geometric mean and single sample maximum *E. coli* concentrations under the TMDL allocation plan are presented in Figure 4.5 and Figure 4.6. Figure 4.5 shows the calendar month geometric mean *E. coli* concentrations for existing as well as under the allocation conditions. Figure 4.6 shows the single sample maximum *E. coli* concentrations under the allocations, as well as under existing conditions.

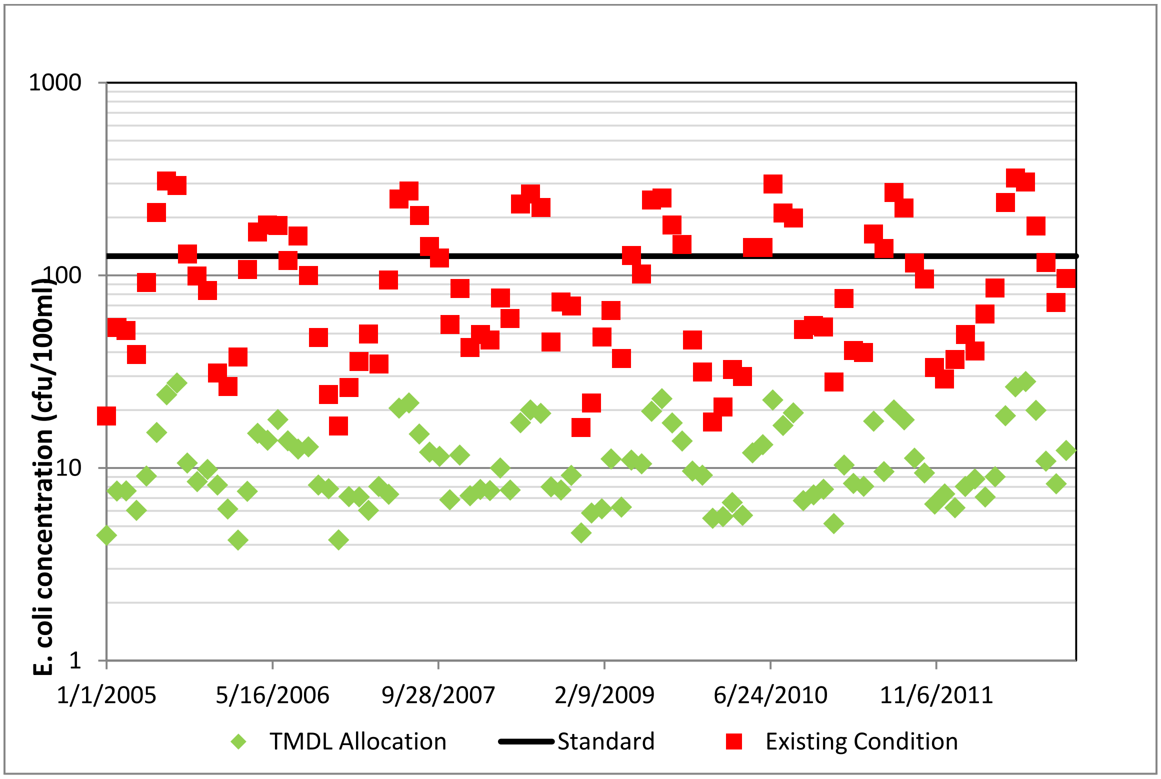


*Figure 4.5. Beech Creek Geometric Mean E. coli Concentrations under Existing and TMDL Conditions.*

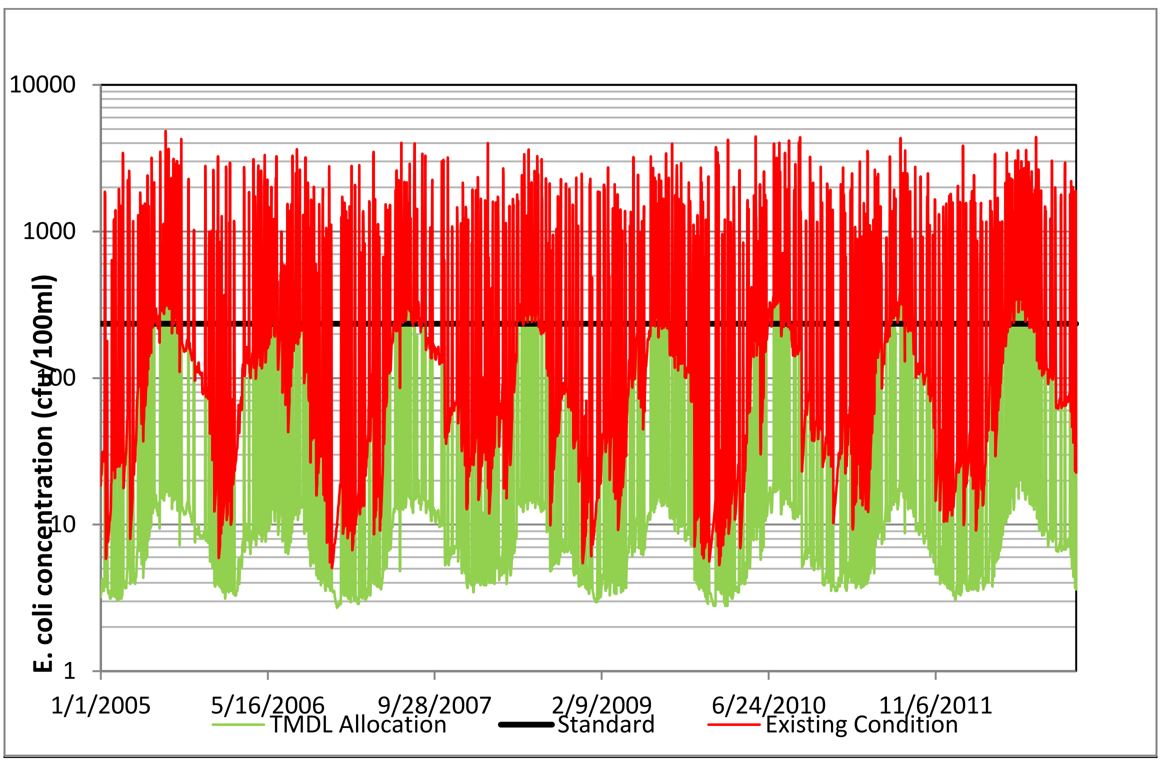


*Figure 4.6. Beech Creek Single Sample Maximum E. coli Concentrations under Existing and TMDL Conditions.*

### 4.4.4 Little Buffalo Creek (VAC-L76R_LFF01A00)

This section presents the wasteload and load allocation plan and TMDL summary for the Little Buffalo Creek impaired segments.

#### *4.4.4.1 Little Buffalo Creek Wasteload Allocation*

There is a single permitted facility discharging bacteria to the Little Buffalo Creek watershed. The DMR data provided showed only very small flow from VA0062421 and showed no bacterial concentration. For the allocation scenarios, the facilities were assumed to discharge at the design flow limits and bacterial concentrations at the existing *E. coli* standard of 126 cfu/100 mL. Table 4.16 shows the existing and allocated loads of dischargers in Little Buffalo Creek.

*Table 4.16. Wasteload Allocations for Little Buffalo Creek Watershed.*

| Permit Number | Facility Name | Existing Load (cfu/year) | Allocated Load (cfu/year) |
|---|---|---|---|
| VA0062421 | Newton Mobile Court Inc. | 6.09E+10 | 6.09E+10 |
| | Future Growth | 0 | 3.89E+10 |
| | Total | 6.09E+10 | 9.98E+10 |

#### *4.4.4.2 Little Buffalo Creek Load Allocation Plan and TMDL Summary*

The requirements to meet the calendar month *E. coli* geometric mean water quality standard of 126 cfu/100 mL and the single sample maximum criterion of 235 cfu/100 mL for the Little Buffalo impaired segment are:

- 100% reduction of the human sources (failed septic systems and straight pipes)
- 99% reduction of the direct livestock instream loading
- 93% reduction of bacteria loading from pasture and hay nonpoint sources
- 93% reduction of bacterial loading from urban nonpoint sources
- 70% reduction of bacteria loading from direct deposition from wildlife
- No reductions from the forested land (wildlife indirect loads)

The estimated load reductions and percent exceedances under each allocation modeling scenario for the Little Buffalo Creek impaired segment is presented in Table 4.17. Table 4.18 details the existing loads, allocated loads, and percent reductions to meet the allocations for each land use/source in the Little Buffalo Creek TMDL watershed.

Table 4.17. Load Allocation Scenario Results for Little Buffalo Creek Watershed.

| Scenario | Percent Reductions to Existing Bacterial Loads | | | | | VADEQ *E. coli* Standard percent violations | |
|---|---|---|---|---|---|---|---|
| | Human Sources[1] | Direct Deposition from Cattle | Non-Point Source – Pasture | Non-point Source - Developed Land uses | Direct Deposition from Wildlife | % > 126 GM | % > 235 cfu/100mL[2] |
| 0 | | | | | | 58.33% | 55.17% |
| 1 | 100 | 100 | | | | 57.29% | 54.35% |
| 2 | 100 | | | | 100 | 0.00% | 24.61% |
| 3 | 100 | 100 | 50 | | | 51.04% | 48.12% |
| 4 | 100 | 99 | 95 | 95 | | 0.00% | 16.90% |
| 5 | 100 | 99 | 95 | 99 | | 0.00% | 14.30% |
| 6 | 100 | 99 | 98 | 99 | | 0.00% | 7.60% |
| 7[3] | 100 | 99 | 93 | 93 | 70 | 0.00% | 9.92% |

[1]Human sources are failed septic systems and straight pipes
[2]The235 cfu/100mL single sample maximum criteria allows up to 10% exceedance
[3] Final TMDL Scenario.

Table 4.18. Annual Average E. coli Load under Existing Conditions and TMDL Allocation for Little Buffalo Creek.

| Bacterial Source | Annual Average *E. coli* Loads (cfu/year) | | Reduction % |
|---|---|---|---|
| | Existing Condition | Allocation | |
| Developed Urban | 8.91E+11 | 6.24E+10 | 93 |
| Crop | 1.91E+09 | 1.91E+09 | 0 |
| Forest | 3.34E+10 | 3.34E+10 | 0 |
| Medium Residential | 2.65E+11 | 1.86E+10 | 93 |
| Low Residential | 9.86E+11 | 6.90E+10 | 93 |
| Pasture and Hay | 8.87E+12 | 6.21E+11 | 93 |
| Wetland | 9.79E+11 | 9.79E+11 | 0 |
| Point Sources | 6.09E+10 | 6.09E+10 | 0 |
| Direct Deposition from Cattle | 1.47E+12 | 1.47E+10 | 99 |
| Direct Deposition from Wildlife | 2.80E+11 | 8.40E+10 | 70 |
| Human Sources[1] | 4.01E+10 | 0.00E+00 | 100 |
| Future Growth | | 3.89E+10 | |
| Total | 1.39E+13 | 1.98E+12 | 85.7 |

[1]Human sources are failed septic systems and straight pipes

Summaries of the TMDL for Little Buffalo Creek are presented in Tables 4.19 and 4.20. The developed TMDL meets the geometric standard and single sample maximum criterion for the impaired segment of Little Buffalo Creek (VAC-L76R_LFF01A00).

Table 4.19. Little Buffalo Creek TMDL (cfu/year) for E. coli.

| Impairment | WLA[1] | LA | MOS | TMDL | Existing Load | Percent Reduction |
|---|---|---|---|---|---|---|
| Little Buffalo Creek (VAC-L76R_LFF01A00) | 9.98E+10 | 1.88E+12 | Implicit | 1.98E+12 | 1.39E+13 | 85.7% |
| VA0062421[1] | 6.09E+10 | | | | | |
| Future Growth[2] | 3.89E+10 | | | | | |

[1]Any issued permit will include bacteria effluent limits in accordance with applicable permit guidance and will ensure the discharge meets the applicable numeric water quality criteria for bacteria at the end-of-pipe.
[2]The WLA reflects an allocation for potential future permits issued for bacteria control.

**Table 4.20. Little Buffalo Creek TMDL (cfu/day) for E. coli.**

| Impairment | WLA[1] | LA | MOS | TMDL | Existing Load | Percent Reduction |
|---|---|---|---|---|---|---|
| Little Buffalo Creek (VAC-L76R_LFF01A00) | 8.85E+08 | 1.67E+10 | Implicit | 1.76E+10 | 1.23E+11 | 85.7% |
| VA0062421[1] | 5.40E+08 | | | | | |
| Future Growth[2] | 3.45E+08 | | | | | |

[1]Any issued permit will include bacteria effluent limits in accordance with applicable permit guidance and will ensure the discharge meets the applicable numeric water quality criteria for bacteria at the end-of-pipe.
[2]The WLA reflects an allocation for potential future permits issued for bacteria control.

The resulting geometric mean and single sample maximum *E. coli* concentrations under the TMDL allocation plan are presented in Figure 4.7 and Figure 4.8. Figure 4.7 shows the calendar month geometric mean *E. coli* concentrations for existing as well as under the allocation conditions. Figure 4.8 shows the single sample maximum *E. coli* concentrations under the allocations, as well as under existing conditions.

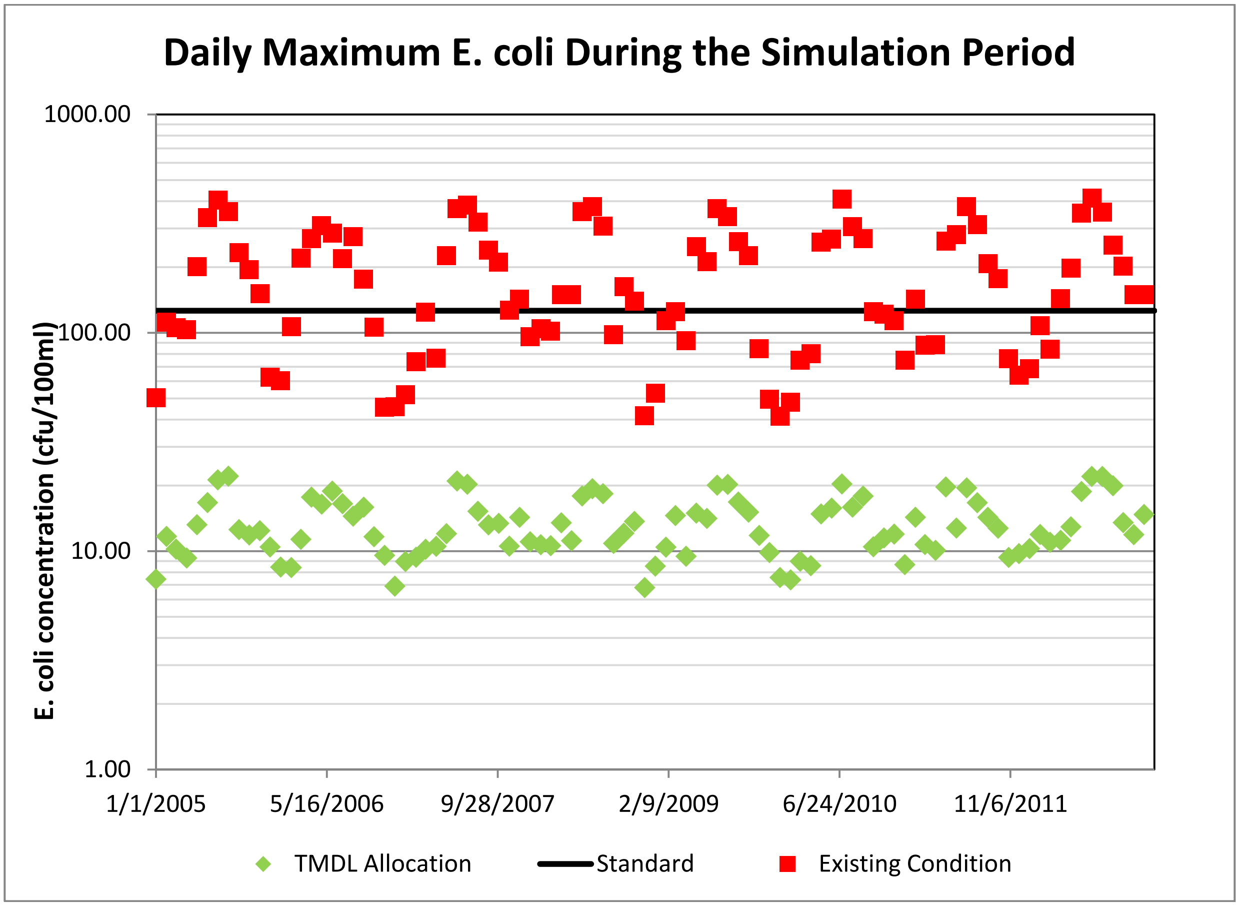


*Figure 4.7. Little Buffalo Creek Geometric Mean E. coli Concentrations under Existing and TMDL Conditions.*

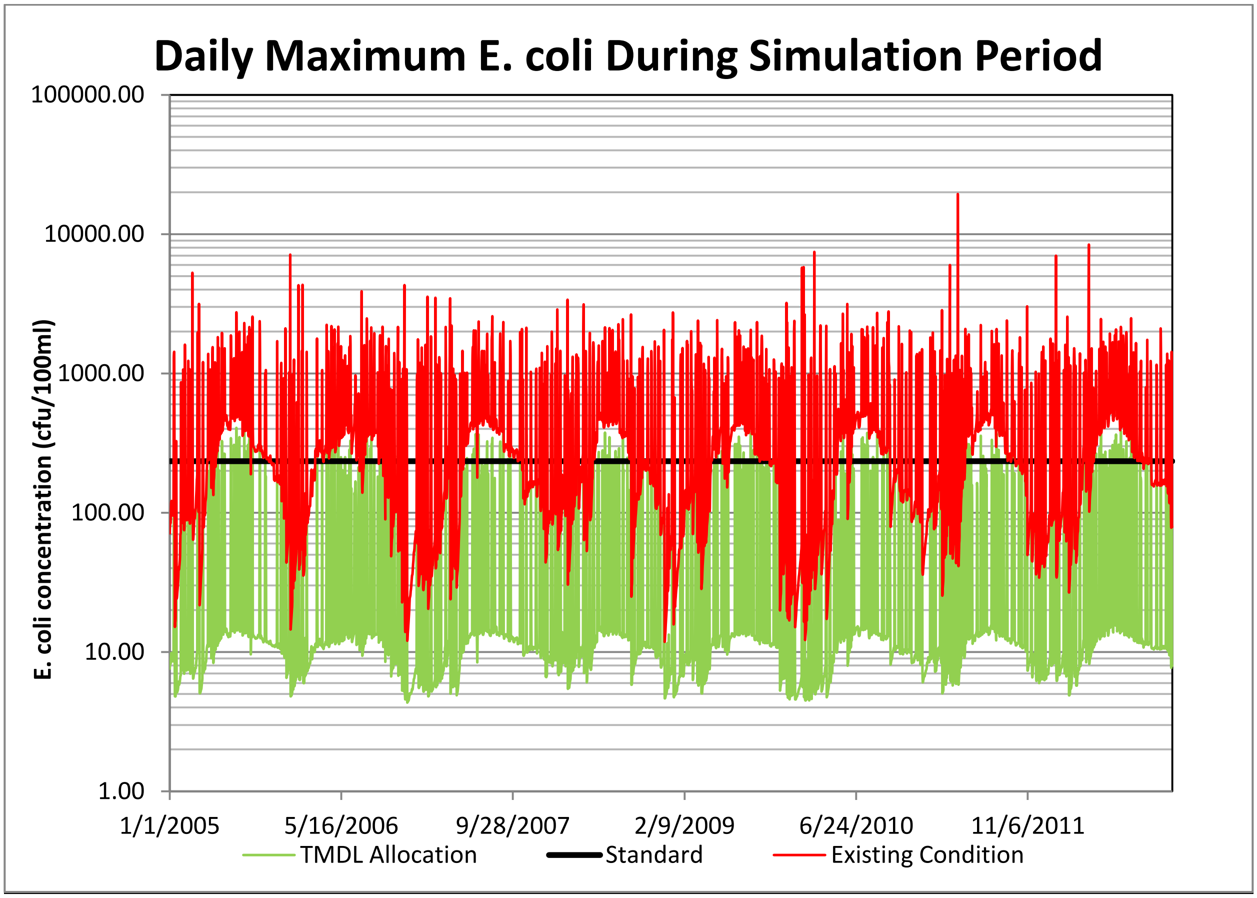


*Figure 4.8. Little Buffalo Creek Single Sample Maximum E. coli Concentrations under Existing and TMDL Conditions.*

## 4.5 Consideration of Critical Condition

The critical condition refers to the "worst case scenario" of environmental conditions in the Hyco River, Aarons Creek, Beech Creek, and Little Buffalo Creek segments. Developing TMDLs to meet the water quality targets under the critical condition will ensure that the targets would also be met under all other conditions.

EPA regulations, 40 CFR 130.7 (c)(1), require TMDLs to take into account critical conditions for stream flow, loading, and water quality parameters. The intent of this requirement is to ensure that the water quality of the impaired streams is protected during times when it is most vulnerable. Critical conditions are important because they describe the combination of factors that cause an exceedance of water quality criteria. They will help in identifying the actions that may have to be undertaken to meet water quality standards.

The Hyco River, Aarons Creek, Beech Creek, and Little Buffalo Creek flow through a predominantly rural setting. The dominant land uses in the basin are forested (57%) and pasture (18%). Potential sources of *E. coli* include run-off from livestock grazing, manure applications, wildlife deposition, point source dischargers, and residential waste.

The model simulation period was selected to include both low flow and high flow conditions, thus covering all of the flow regimes. The long term simulation used in this TMDL will guarantee that the critical conditions were addressed in the TMDL.

## 4.6 Consideration of Seasonal Variations

Seasonal variations involve changes in stream flow and water quality because of hydrologic and climatological patterns. Seasonal variations were explicitly included in the modeling approach for this TMDL. The continuous simulation model developed for this TMDL explicitly incorporated the seasonal variations of rainfall, runoff, and fecal coliform wash-off by using an hourly time-step. In addition, fecal coliform accumulation rates for each land use were developed on a monthly basis. This allowed for the consideration of temporal variability in fecal coliform loading within the watershed.

# 5.0 TMDL IMPLEMENTATION

The goal of the TMDL program is to establish a three-step path that will lead to attainment of water quality standards. The first step in the process is to develop TMDLs that will result in meeting water quality standards. The second step is to develop a TMDL Implementation Plan. The final step is to implement the TMDL Implementation Plan and to monitor stream water quality to determine if water quality standards are being attained.

Once a TMDL has been approved by the State Water Control Board (SWCB) and then the USEPA, measures must be taken to reduce pollutant levels in the stream. These measures, which can include the use of better treatment technology and the installation of BMPs, are implemented in an iterative process that is described along with specific BMPs in the Implementation Plan. The process for developing an Implementation Plan has been described in the "TMDL Implementation Plan Guidance Manual", published in July 2003 and available upon request from the DEQ TMDL project staff or at http://www.deq.virginia.gov/Programs/Water/WaterQualityInformationTMDLs/TMDL/TMDLImplementation/TMDLImplementationPlanGuidanceManual.aspx . With successful completion of Implementation Plans, Virginia begins the process of restoring impaired waters and enhancing the value of this important resource. Additionally, development of an approved Implementation Plan will improve a locality's chances for obtaining financial and technical assistance during implementation.

Watershed stakeholders will have opportunity to participate in the development of the TMDL Implementation Plan, which is the next step in the TMDL process. Specific goals for BMP implementation will be established as part of the Implementation Plan development. VADEQ will work closely with watershed stakeholders, interested state agencies, and support groups to develop an acceptable Implementation Plan that will result in meeting the water quality standard.

## 5.1. Reasonable Assurance for Implementation

### 5.1.1 TMDL Monitoring

VADEQ will monitor the impaired streams in accordance with its ambient monitoring program in the Hyco River, Aarons Creek, Beech Creek, and Little Buffalo Creek. VADEQ will continue to use data from the monitoring stations to evaluate reductions in pollutants and the effectiveness of TMDL implementation in attainment of the general water quality standard. VADEQ's Ambient Watershed Monitoring Plan for conventional pollutants calls for watershed monitoring to take place on a rotating basis, bi-monthly for two consecutive years of a six-year cycle. VADEQ staff, in cooperation with the Implementation Plan Steering Committee and local stakeholders, will determine the purpose, location, parameters, frequency, and duration of the monitoring. Whenever possible, the location of the follow-up monitoring station(s) will be the same as the listing station. At a minimum, the monitoring station must be representative of the original impaired segment. The Annual Water Monitoring Plan prepared by each VADEQ Regional Office will outline the details of the follow-up monitoring. Other agency personnel, watershed stakeholders, etc. may provide input on the Annual Water Monitoring Plan.

September 30 of each year is the deadline for the recommendations made to the VADEQ regional TMDL coordinator.

To demonstrate that the watershed is meeting water quality standards in watersheds where corrective actions have taken place (whether or not a TMDL or TMDL Implementation Plan has been completed), VADEQ must meet the minimum data requirements from the original listing station or a station representative of the originally listed segment. The minimum data requirement for conventional pollutants (bacteria, dissolved oxygen, etc.) is bi-monthly monitoring for two consecutive years. For biological monitoring, the minimum requirement is two consecutive samples (one in the spring and one in the fall) in a one-year period.

### 5.1.2 Regulatory Framework

#### *5.1.2.1 Federal Regulations*

While section 303(d) of the Clean Water Act and current USEPA regulations do not require the development of TMDL implementation plans as part of the TMDL process, they do require reasonable assurance that the load and wasteload allocations can and will be implemented. Federal regulations also require that all new or revised National Pollutant Discharge Elimination System (NPDES) permits must be consistent with the assumptions and requirements of any applicable TMDL WLA (40 CFR §122.44 (d)(1)(vii)(B)). All such permits should be submitted to USEPA for review.

#### *5.1.2.2 State Regulations*

Additionally, Virginia's 1997 Water Quality Monitoring, Information and Restoration Act (WQMIRA) directs the State Water Control Board to "develop and implement a plan to achieve fully supporting status for impaired waters" (Section 62.1-44.19.7). WQMIRA also establishes that the implementation plan shall include the date of expected achievement of water quality objectives, measurable goals, corrective actions necessary and the associated costs, benefits and environmental impacts of addressing the impairments. USEPA outlines the minimum elements of an approvable implementation plan in its 1999 "Guidance for Water Quality-Based Decisions: The TMDL Process." The listed elements include implementation actions/management measures, timelines, legal or regulatory controls, time required to attain water quality standards, monitoring plans and milestones for attaining water quality standards.

For the implementation of the WLA component of each TMDL, the Commonwealth utilizes the Virginia NPDES (VPDES) program, which typically includes consideration of the WQMIRA requirements during the permitting process. Requirements of the permit process should not be duplicated in the TMDL process and implementation plan development, especially those implemented through water quality based effluent limitations. However, those requirements that are considered BMPs may be enhanced by inclusion in the TMDL IP, and their connection to the identified impairment. New point source discharge permit will be allowed under the waste load allocation provided they meet all applicable VPDES requirements.

5.1.3 Implementation Funding Sources

Implementation funding sources will be determined during the implementation planning process by the local watershed stakeholder planning group. Potential sources of funding include Section 319 funding for Virginia's Nonpoint Source Management Program, the U.S. Department of Agriculture's Conservation Reserve Enhancement and Environmental Quality Incentive Programs, the Virginia State Revolving Loan Program, and the Virginia Water Quality Improvement Fund, although other sources are also available for specific projects and regions of the state. The TMDL Implementation Plan Guidance Manual contains additional information on funding sources, as well as government agencies that might support implementation efforts and suggestions for integrating TMDL implementation with other watershed planning efforts.

5.1.4 Attainability of Primary Contact Recreation Use

In some streams for which TMDLs have been developed, water quality modeling indicates that even after removal of all bacteria sources (other than wildlife), the stream will not attain standards under all flow regimes at all times. These streams may not be able to attain standards without some reduction in wildlife load. **Virginia and EPA are not proposing the elimination of wildlife to allow for the attainment of water quality standards.** While managing overpopulations of wildlife remains as an option to local stakeholders, the reduction of wildlife or changing a natural background condition is not the intended goal of a TMDL. Additionally, other factors may prevent the stream from attaining the primary contact recreation use.

To address this issue, Virginia proposed during its latest triennial water quality standards review a new "secondary contact" category for protecting the recreational use in state waters. On March 25, 2003, the Virginia State Water Control Board adopted criteria for "secondary contact recreation" which means "a water-based form of recreation, the practice of which has a low probability for total body immersion or ingestion of waters (examples include but are not limited to wading, boating, and fishing)". These new criteria became effective on February 12, 2004 (SWCB, 2011).

In order for the new criteria to apply to a specific stream segment, the primary contact recreational use must be removed. To remove a designated use, the state must demonstrate 1) that the use is not an existing use, 2) that downstream uses are protected, and 3) that the source of contamination is natural and uncontrollable by effluent limitations and by implementing cost-effective and reasonable best management practices for nonpoint source control (9 VAC 25-260-10). This and other information is collected through a special study called a Use Attainability Analysis (UAA). All site-specific criteria or designated use changes must be adopted as amendments to the water quality standards regulations. Watershed stakeholders and EPA will be able to provide comment during this process (VADEQ, 2014).

The process to address potentially unattainable reductions based on the above is as follows: First is the development of a stage 1 scenario such as those presented previously in this chapter. The pollutant reductions in the stage 1 scenario are targeted only at the controllable, anthropogenic bacteria sources identified in the TMDL, setting aside control strategies for wildlife except for cases of nuisance overpopulations. During the implementation of the stage 1 scenario, all controllable sources would be reduced to the maximum extent practicable using the iterative approach described in Section 6-2 above. VADEQ will re-assess water quality in the stream during and subsequent to the implementation of the stage 1 scenario to determine if the water quality standard is attained. This effort will also evaluate if the modeling assumptions were correct. If water quality standards are not being met, and no additional cost-effective and reasonable best management practices can be identified, a UAA may be initiated with the goal of re-designating the stream for secondary contact recreation.

5.1.5. Reasonable Assurance Summary

Watershed stakeholders will have opportunities to provide input and to participate in the development of the implementation plan, which will also be supported by regional and local offices of VADEQ, VADCR, and other cooperating agencies.

# 6.0 PUBLIC PARTICIPATION

The bacterial TMDLs for the Hyco River, Aarons Creek, Beech Creek, and Little Buffalo Creek were developed with the participation and input of the public at various stages of the process.

A conference call with the Technical Advisory Committee was held on December 12, 2013 to introduce to the agency stakeholders bacteria TMDLs in Hyco River, Aarons Creek, Little Buffalo Creek, and Beech Creek watersheds along with the Coleman Creek benthic TMDL. During the call, the TMDL projects were introduced, and the proposed modeling approach and the data available to support the analysis were discussed with the attendees. The attendees included representatives from VADEQ, Halifax County, Natural Resources Conservation Service in Halifax, and Department of Health.

A number of follow-up consultations via the phone with individual members of the Technical Advisory Committee were conducted to discuss available data and solicit any anecdotal information about the watersheds.

The first Public Meeting was held at the Midway Volunteer Fire Department in Virgilina, Virginia on January 9, 2014. The scope of the meeting included both the bacteria and benthic impairments in the Hyco River, Aarons Creek, Little Buffalo Creek, Coleman Creek and Beech Creek. During the meeting, presentations were made to introduce the TMDL process and the local stream impairments. The proposed modeling approach and data available were also presented. Comments were solicited from the participants during the meeting. A news article on the local Gazette-Virginian paper was published on May 11, 2014 by the local journalist who attended the public meeting.

A final public meeting will be held on July 10, 2014 to present the draft TMDL report for bacteria and benthic impairments in the aforementioned watersheds. A 30-day public comment period will follow the public meeting. Comments received during the public meeting and the 30-day period will be evaluated and addressed.

# 7.0 REFERENCES


AVMA. 2013. American Veterinary Medical Association Website. Available at: https://www.avma.org/Pages/home.aspx

Bicknell, B.R., J.C. Imhoff, J.L. Kittle, Jr., T.H. Jobes, A.S. Donigian, Jr. and Johanson, R.C. 2001. Hydrological Simulation Program – FORTRAN (HSPF) User's Manual for Version 12. Athens, GA: National Exposure Research Laboratory, USEPA, in cooperation with Reston, VA: Water Resources Division, USGS. Available at: http://www.epa.gov/waterscience/basins/b3docs/HSPF12.zip

Doherty, J., C. Muffels, J. Rumbaugh, and M. Tonkin, 2014. PEST: Model-Independent Parameter Estimation & Uncertainty Analysis. Available at: http://www.pesthomepage.org/Home.php

Duda, P., J. Kittle, Jr., M. Gray, P. Hummel, R. Dusenbury. 2001. WinHSPF Version 2.0, An Interactive Windows Interface to HSPF, User's Manual. Washington, D.C.: USEPA. Available at: http://www.epa.gov/athens/research/ftable/toc_intr.pdf

ESRI, 2014. ArcGIS for Desktop. The Professional GIS Authoring Application. Available at: http://www.esri.com/software/arcgis/arcgis-for-desktop

Hummel, P., J. Kittle, Jr., and M. Gray, 2001. WDMUtil Version 2.0: A Tool for Managing Watershed Modeling Time-Series Data, User's Manual. Washington, D.C.: USEPA. Available at: http://hspf.com/ftp/basins3/doc/WDMUtil.pdf

MRLC. 2013. National Land Cover Database 2006 (NLCD2006). Available at: http://www.mrlc.gov/nlcd06_data.php

NCDC. 2013. Climate Data Online. Available at: http://www.ncdc.noaa.gov/cdo-web/

SWCB. 2011. 9 VAC 25-260 Virginia Water Quality Standards. Statutory Authority: § 62.1-44.15 3a of the Code of Virginia. With Amendments Effective January 6, 2011. Available at: http://water.epa.gov/scitech/swguidance/standards/wqslibrary/upload/vawqs.pdf

U.S. Census Bureau. 2010. 2010 U.S. Census Data for Virginia. Available at: http://www.census.gov/

U.S. Census Bureau. 2014. U.S. Census QuickFacts. Available at: http://quickfacts.census.gov/qfd/index.html

USDA. 2013a. USDA – Web Soil Survey. Available at: http://websoilsurvey.sc.egov.usda.gov/App/HomePage.htm

USDA. 2013b. USDA – National Agricultural Statistics by State. Available at: http://www.nass.usda.gov/Statistics_by_State/

USEPA, 1985. Rates, Constants, and Kinetics Formulations in Surface Water Quality Modeling (Second Edition). EPA/600/3-85/040. Athens, GA: Environmental Research Laboratory, USEPA. Available at: http://nepis.epa.gov/Adobe/PDF/9100R3IW.PDF

USEPA, 1991. Guidance for Water Quality-Based Decisions: The TMDL Process. EPA-400/4-91-001. Washington, D.C.: Office of Water, USEPA. Available at: http://water.epa.gov/lawsregs/lawsguidance/cwa/tmdl/decisions_index.cfm

USEPA, 2000. BASINS Technical Note 6: Estimating Hydrology and Hydraulic Parameters for HSPF. EPA-823-R00-012. Washington, D.C.: Office of Water, USEPA. Available at: http://water.epa.gov/scitech/datait/models/basins/upload/2000_08_14_BASINS_tecnote6.pdf.

USEPA, 2001. Protocol for Developing Pathogen TMDLs. EPA 841-R-00-002. Washington, D.C.: Office of Water, USEPA. Available at: http://www.epa.gov/owow/tmdl/pathogen_all.pdf.

USEPA, 2007. Options for Expressing Daily Loads in TMDLs (Draft). Washington, D.C.: Office of Wetlands, Oceans and Watersheds, USEPA. Available at: http://www.epa.gov/owow/tmdl/draft_daily_loads_tech.pdf

USEPA, 2013. BASINS (Better Assessment Science Integrating point & Non-point Sources). Available at: http://water.epa.gov/scitech/datait/models/basins/index.cfm

USGS, 2014. HSPexp: Expert System for Calibration of HSPF. Available at: http://water.usgs.gov/software/HSPexp/

VADEQ, 2001. Total Maximum Daily Load Program, A Ten Year Implementation Plan-Report to the Governor, House of Committees, and Senate Committees, November 1, 2000. Richmond, VA: VADEQ. Available at: http://www.deq.state.va.us/tmdl/reports/hb30.pdf

VADEQ, 2002. Dodd Creek Watershed, Virginia. Richmond, VA: VADEQ. Available at: http://www.deq.virginia.gov/portals/0/DEQ/Water/TMDL/apptmdls/newrvr/dodd.pdf

VADEQ, 2003. Guidance Memo No. 03-2012 HSPF model Calibration and Verification for Bacteria TMDLs. Richmond, VA: VADEQ. Available at: http://www.deq.virginia.gov/Portals/0/DEQ/Water/Guidance/032012.pdf

VADEQ, 2008. Bacteria TMDL Development for the Dan River, Blackberry Creek, Byrds Branch, Double Creek, Fall Creek, Leatherwood Creek, Marrowbone Creek, North Fork Mayo River, South Fork Mayo River, Smith River, Sandy Creek, and Sandy River Watersheds. Richmond, VA: VADEQ. Available at: http://www.deq.virginia.gov/portals/0/DEQ/Water/TMDL/apptmdls/roankrvr/danec.pdf

VADEQ, 2012. Final 2010 305(b)/303(d) Water Quality Assessment Integrated Report. Richmond, VA: VADEQ. Available at: http://www.deq.virginia.gov/Programs/Water/WaterQualityInformationTMDLs/WaterQualityAssessments/2010305b303dIntegratedReport.aspx

VADEQ, 2012. Final 2012 305(b)/303(d) Water Quality Assessment Integrated Report. Richmond, VA: VADEQ. Available at: http://www.deq.virginia.gov/Programs/Water/WaterQualityInformationTMDLs/WaterQualityAssessments/2012305(b)303(d)IntegratedReport.aspx

VADEQ. 2014. Frequently Asked Questions about TMDLs. Richmond, VA: VADEQ. Available at: http://www.deq.virginia.gov/Programs/Water/WaterQualityInformationTMDLs/TMDL/FrequentlyAskedQuestions.aspx.

# APPENDIX A. LAND USE DISTRIBUTION FOR MODEL SUB-WATERSHED

Table A.1. Land use Distribution.

| Sub-watershed | Open Water | Developed, Open Space | Developed, Low Intensity | Developed, Medium Intensity | Developed, High Intensity | Barren Land | Deciduous Forest | Evergreen Forest | Mixed Forest | Shrub /Scrub | Cultivated Crops | Woody Wetlands | Emergent Herbaceous Wetlands | Pasture | Hay | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Aarons_1 | 22.2 | 94.7 | 31.4 | 2.0 | - | - | 1,352.2 | 270.2 | 115.9 | 61.4 | 4.9 | 90.5 | - | 564.2 | 62.5 | 2,672.1 |
| Aarons_10 | - | 18.9 | - | - | - | - | 228.4 | 46.7 | 42.0 | 8.2 | 4.7 | 6.0 | - | 166.8 | 37.4 | 559.1 |
| Aarons_11 | 6.0 | 87.8 | 1.1 | - | - | - | 797.3 | 136.3 | 105.6 | 90.3 | 57.2 | 10.0 | - | 544.0 | 151.5 | 1,987.1 |
| Aarons_12 | 3.3 | 32.5 | - | - | - | - | 351.2 | 59.4 | 52.7 | 10.2 | 4.2 | - | - | 209.3 | 94.1 | 816.9 |
| Aarons_13 | 1.1 | 5.3 | - | - | - | - | 145.4 | 1.1 | 4.2 | 19.3 | 4.7 | - | - | 51.8 | | 231.5 |
| Aarons_14 | - | 18.0 | - | - | - | 2.4 | 395.9 | 22.9 | 26.9 | 17.3 | 10.5 | 7.1 | - | 157.5 | 40.9 | 699.4 |
| Aarons_15 | 3.3 | 42.9 | 0.7 | 0.2 | - | - | 617.1 | 72.9 | 49.1 | 34.7 | 18.5 | 2.9 | - | 577.6 | 131.2 | 1,551.2 |
| Aarons_16 | 1.1 | 23.8 | 1.8 | - | - | - | 436.8 | 147.7 | 63.6 | 25.8 | 25.8 | - | - | 355.8 | 19.1 | 1,101.3 |
| Aarons_17 | 4.7 | 27.6 | - | - | - | - | 125.2 | 17.8 | 39.8 | 29.1 | 11.3 | - | - | 126.5 | 7.1 | 389.2 |
| Aarons_18 | - | 76.9 | 6.2 | 2.0 | - | 1.8 | 396.3 | 74.1 | 46.5 | 40.7 | 3.8 | - | - | 213.9 | 50.9 | 913.2 |
| Aarons_19 | 2.0 | 103.9 | 2.9 | 0.2 | - | - | 626.7 | 86.5 | 43.4 | 54.3 | 8.0 | 20.7 | - | 167.5 | 215.9 | 1,331.9 |
| Aarons_2 | - | 1.8 | - | - | - | - | 20.9 | 4.2 | - | 0.4 | - | 4.0 | - | 3.1 | | 33.1 |
| Aarons_20 | 1.3 | 65.4 | 1.6 | - | - | 3.3 | 718.1 | 140.6 | 56.9 | 37.4 | 16.9 | 3.3 | - | 179.5 | 180.4 | 1,404.6 |
| Aarons_21 | 1.6 | 42.0 | - | - | - | - | 262.9 | 114.8 | 12.2 | 4.4 | - | 5.3 | - | 15.3 | 140.8 | 599.4 |
| Aarons_22 | 3.6 | 25.4 | - | - | - | - | 250.6 | 35.6 | 30.0 | 9.6 | - | - | 1.8 | 35.6 | 116.1 | 508.2 |
| Aarons_23 | - | 35.1 | 1.6 | - | - | - | 302.2 | 61.8 | 36.7 | 18.2 | 4.0 | 20.2 | - | 19.6 | 159.5 | 659.0 |
| Aarons_24 | - | 20.5 | 0.4 | - | - | - | 359.2 | 18.2 | 39.8 | 21.8 | 3.8 | 4.2 | - | 19.1 | 115.4 | 602.5 |
| Aarons_25 | 4.4 | 41.6 | 2.2 | - | - | 1.1 | 741.0 | 55.8 | 46.7 | 186.4 | 19.6 | 56.5 | - | 211.5 | 320.2 | 1,687.1 |
| Aarons_26 | - | 11.6 | - | - | - | 29.4 | 743.9 | 247.7 | 115.0 | 80.5 | 3.8 | 22.9 | - | 177.2 | 191.5 | 1,623.5 |
| Aarons_27 | 7.1 | 28.9 | - | - | - | - | 676.7 | 301.1 | 118.3 | 40.0 | - | 7.6 | - | 64.5 | 149.4 | 1,393.7 |
| Aarons_28 | 1.8 | 34.5 | - | - | - | - | 557.1 | 115.4 | 48.5 | 73.8 | 30.5 | 8.0 | - | 157.5 | 297.3 | 1,324.4 |
| Aarons_29 | - | 27.4 | 2.4 | - | - | 32.0 | 536.9 | 127.7 | 40.9 | 16.0 | 32.5 | 11.3 | - | 85.8 | 354.9 | 1,267.9 |
| Aarons_3 | - | 33.1 | 2.7 | - | - | - | 313.8 | 97.2 | 39.1 | 17.6 | 8.2 | 13.1 | - | 149.4 | 35.8 | 710.1 |
| Aarons_30 | 1.6 | 37.8 | - | - | - | 16.7 | 812.2 | 100.7 | 95.2 | 12.9 | - | 20.2 | - | 59.4 | 127.0 | 1,283.7 |
| Aarons_31 | 1.1 | 30.9 | 2.2 | - | - | 3.8 | 495.7 | 45.4 | 24.7 | 10.2 | 4.0 | 19.3 | - | 47.4 | 332.7 | 1,017.5 |
| Aarons_32 | - | 1.8 | 0.7 | - | - | - | 71.2 | 10.9 | 2.7 | 0.2 | - | - | - | 0.4 | 4.4 | 92.3 |
| Aarons_33 | - | 8.9 | 1.1 | - | - | - | 273.3 | 70.3 | 34.7 | 4.2 | - | - | - | 12.5 | 28.2 | 433.2 |
| Aarons_34 | 1.3 | 72.5 | 3.3 | - | - | - | 1,046.8 | 385.9 | 168.6 | 79.4 | - | 6.4 | - | 171.0 | 175.9 | 2,111.2 |
| Aarons_35 | - | 30.9 | 1.3 | - | - | - | 252.6 | 145.2 | 86.1 | 18.2 | - | 1.8 | - | 112.5 | 48.5 | 697.2 |
| Aarons_36 | - | 61.8 | 1.1 | - | - | 1.3 | 548.9 | 191.5 | 52.0 | 47.4 | - | 17.1 | - | 59.8 | 113.6 | 1,094.6 |
| Aarons_37 | 1.6 | 38.7 | - | - | - | - | 412.3 | 106.7 | 47.6 | 4.2 | 1.1 | 13.8 | - | 61.2 | 87.2 | 774.4 |
| Aarons_38 | 1.3 | 49.6 | 3.8 | - | - | 2.0 | 196.4 | 65.2 | 36.3 | 38.9 | 22.2 | - | - | 209.5 | 70.7 | 695.9 |
| Aarons_39 | 8.7 | 34.7 | 1.1 | 1.6 | - | - | 255.3 | 260.9 | 78.7 | 32.2 | 31.8 | - | - | 245.7 | 51.6 | 1,002.3 |
| Aarons_4 | - | 23.1 | - | - | - | - | 239.7 | 167.2 | 41.8 | 3.6 | - | - | - | 91.2 | 16.0 | 582.7 |
| Aarons_40 | 6.2 | 40.5 | 1.1 | - | - | 2.4 | 611.6 | 224.2 | 100.7 | 76.3 | 13.3 | 3.6 | - | 391.0 | 64.7 | 1,535.6 |
| Aarons_5 | 2.7 | 106.1 | - | 1.1 | - | - | 928.1 | 230.6 | 90.7 | 45.4 | 20.5 | 36.5 | - | 730.6 | 179.7 | 2,371.8 |
| Aarons_6 | - | 37.1 | - | - | - | 1.1 | 149.9 | 30.5 | 10.2 | 1.1 | 17.8 | 0.7 | - | 185.0 | 109.2 | 542.6 |
| Aarons_7 | 4.0 | 69.2 | 4.7 | - | - | 0.2 | 672.7 | 280.0 | 110.8 | 42.9 | 37.8 | 20.5 | - | 430.8 | 119.0 | 1,792.5 |

| Sub-watershed | Open Water | Developed, Open Space | Developed, Low Intensity | Developed, Medium Intensity | Developed, High Intensity | Barren Land | Deciduous Forest | Evergreen Forest | Mixed Forest | Shrub /Scrub | Cultivated Crops | Woody Wetlands | Emergent Herbaceous Wetlands | Pasture | Hay | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Aarons_8 | 2.7 | 93.4 | 12.0 | 2.9 | - | 2.7 | 866.7 | 336.9 | 107.0 | 70.1 | 13.1 | 59.8 | - | 582.7 | 116.1 | 2,266.0 |
| Aarons_9 | - | 3.3 | - | - | - | - | 42.7 | 6.7 | 6.4 | - | - | - | - | 15.1 | 3.3 | 77.6 |
| Beech_1 | - | 4.2 | - | - | - | - | 12.2 | 14.7 | 3.1 | - | - | 3.3 | - | 4.4 | 6.7 | 48.7 |
| Beech_10 | - | 18.9 | - | - | - | 6.9 | 111.2 | 28.7 | 14.7 | 9.6 | 15.1 | - | - | 198.2 | 23.1 | 426.3 |
| Beech_11 | - | - | - | - | - | - | 7.8 | 0.9 | - | - | - | 6.9 | - | 2.2 | 0.7 | 18.5 |
| Beech_12 | 2.7 | 14.2 | - | - | - | 10.9 | 179.7 | 54.7 | 26.5 | 25.8 | 8.2 | 1.8 | - | 171.2 | 45.1 | 540.9 |
| Beech_13 | - | 13.1 | - | - | - | - | 116.8 | 24.9 | 4.9 | - | - | 0.7 | - | 167.2 | 47.1 | 374.7 |
| Beech_14 | - | 4.9 | - | - | - | 0.2 | 75.2 | 12.7 | 3.8 | 2.4 | - | - | - | 82.5 | 19.6 | 201.3 |
| Beech_15 | 2.0 | 23.1 | 1.1 | - | - | - | 191.3 | 104.1 | 37.1 | 10.9 | 3.8 | - | - | 69.8 | 47.1 | 490.4 |
| Beech_2 | - | 4.7 | - | - | - | - | 52.7 | 8.5 | 1.8 | 2.4 | - | 8.7 | - | 4.9 | 1.6 | 85.2 |
| Beech_3 | - | 4.0 | - | - | - | - | 138.6 | 25.4 | 10.5 | 12.9 | - | 4.9 | - | 21.1 | 12.7 | 230.0 |
| Beech_4 | - | - | - | - | - | - | 7.6 | 0.9 | - | - | - | 5.3 | - | - | | 13.8 |
| Beech_5 | 1.3 | 5.3 | - | - | - | - | 133.4 | 66.9 | 14.5 | 24.9 | - | 19.8 | - | 27.1 | 36.3 | 329.6 |
| Beech_6 | - | 10.5 | - | - | - | - | 194.4 | 14.9 | 39.1 | 16.7 | 7.1 | 4.7 | - | 111.0 | 41.8 | 440.1 |
| Beech_7 | 2.0 | 6.4 | - | - | - | - | 187.9 | 11.1 | 16.2 | 3.6 | 8.5 | 2.9 | - | 45.4 | 16.5 | 300.5 |
| Beech_8 | - | 3.1 | - | - | - | - | 232.4 | 48.7 | 23.1 | 8.7 | 8.7 | - | - | 186.4 | 34.0 | 545.1 |
| Beech_9 | 1.3 | 5.1 | - | - | - | - | 79.8 | 13.3 | 2.4 | - | 11.8 | 4.0 | - | 29.6 | 13.6 | 161.0 |
| Hyc1 | 34.9 | 80.7 | 11.3 | - | - | 13.6 | 641.2 | 320.7 | 67.2 | 34.2 | 10.5 | 52.5 | 1.8 | 314.5 | | 1,542.8 |
| Hyc10 | 6.9 | 83.8 | 23.4 | 3.6 | - | 1.6 | 615.6 | 447.0 | 81.6 | 53.2 | - | 38.0 | - | 393.0 | 27.6 | 1,775.2 |
| Hyc11 | - | 9.1 | - | - | - | - | 217.1 | 46.5 | 40.9 | 2.4 | - | 89.4 | - | 66.7 | 18.0 | 490.2 |
| Hyc12 | 1.3 | 44.7 | - | - | - | 8.7 | 1,084.0 | 305.6 | 172.1 | 20.2 | - | 214.2 | - | 235.7 | 29.1 | 2,115.6 |
| Hyc13 | 4.7 | 117.9 | 42.3 | 4.7 | 1.3 | 9.8 | 683.9 | 451.7 | 99.6 | 81.8 | 3.6 | 89.4 | - | 499.7 | 74.1 | 2,164.3 |
| Hyc14 | 6.0 | 7.3 | - | - | - | 2.9 | 124.3 | 126.3 | 22.9 | 3.1 | - | 63.2 | 4.7 | 63.8 | 0.7 | 425.2 |
| Hyc15 | 1.1 | 11.1 | - | - | - | - | 90.1 | 24.9 | 12.2 | 7.6 | - | 29.4 | - | 99.4 | 9.3 | 285.1 |
| Hyc16 | 3.8 | 66.1 | 1.6 | - | - | 2.9 | 668.3 | 287.3 | 97.6 | 50.0 | 6.4 | 36.0 | - | 590.5 | 39.4 | 1,849.9 |
| Hyc17 | 1.3 | 54.5 | - | - | - | - | 444.1 | 243.7 | 61.8 | 24.5 | 1.8 | 51.4 | - | 304.5 | - | 1,163.3 |
| Hyc18 | - | 23.4 | - | - | - | - | 185.7 | 55.2 | 17.8 | 34.5 | - | 1.6 | - | 179.0 | - | 437.7 |
| Hyc19 | - | 17.8 | 0.2 | - | - | - | 170.1 | 116.8 | 36.7 | 29.6 | - | 15.3 | - | 132.3 | - | 507.3 |
| Hyc2 | 7.8 | 19.3 | 6.7 | - | - | 1.1 | 304.9 | 171.0 | 35.1 | - | - | 25.6 | - | 14.7 | - | 575.1 |
| Hyc20 | - | 54.7 | - | - | - | 44.0 | 472.6 | 406.5 | 181.0 | 17.3 | 3.6 | - | - | 357.4 | 10.7 | 1,547.9 |
| Hyc21 | - | 12.7 | - | - | - | - | 98.1 | 13.1 | 5.8 | 1.3 | - | - | - | 97.0 | - | 224.6 |
| Hyc22 | - | - | - | - | - | - | 10.7 | 3.1 | 2.4 | - | - | 16.9 | - | - | - | 33.1 |
| Hyc23 | - | 3.8 | 12.5 | 1.1 | - | - | 21.8 | 82.7 | 14.9 | - | - | 115.6 | - | - | - | 252.4 |
| Hyc24 | 2.0 | 108.3 | 31.4 | 3.8 | - | - | 837.3 | 356.7 | 120.1 | 10.9 | 5.3 | 343.4 | - | 551.8 | - | 2,354.5 |
| Hyc25 | - | 71.8 | 0.9 | - | - | - | 783.1 | 361.8 | 95.0 | 236.2 | 3.6 | 279.3 | 3.1 | 605.6 | 20.9 | 2,461.2 |
| Hyc26 | - | 49.4 | - | - | - | 1.1 | 431.7 | 308.5 | 144.8 | 79.2 | 16.0 | 210.6 | - | 330.5 | 32.0 | 1,603.7 |
| Hyc27 | - | - | - | - | - | - | 2.0 | 1.8 | - | - | - | 17.1 | - | - | - | 20.9 |
| Hyc28 | 1.1 | 32.2 | - | - | - | - | 189.7 | 254.6 | 57.2 | 70.7 | 10.0 | 67.8 | - | 175.7 | 67.8 | 926.9 |
| Hyc29 | 1.8 | 45.1 | 2.0 | - | - | 1.1 | 536.0 | 276.9 | 79.6 | 33.4 | 8.9 | 26.9 | - | 354.3 | 18.9 | 1,384.9 |

| Sub-watershed | Open Water | Developed, Open Space | Developed, Low Intensity | Developed, Medium Intensity | Developed, High Intensity | Barren Land | Deciduous Forest | Evergreen Forest | Mixed Forest | Shrub /Scrub | Cultivated Crops | Woody Wetlands | Emergent Herbaceous Wetlands | Pasture | Hay | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Hyc3 | 9.1 | 101.2 | 15.8 | - | - | 29.8 | 586.7 | 365.6 | 104.5 | 7.1 | 11.8 | 101.0 | - | 489.7 | - | 1,788.1 |
| Hyc30 | 1.3 | 46.9 | 2.4 | - | - | 6.4 | 607.6 | 337.6 | 139.9 | 48.5 | 6.2 | 13.3 | - | 385.6 | 63.6 | 1,659.5 |
| Hyc31 | - | 34.7 | 1.3 | - | - | 1.6 | 701.0 | 269.8 | 130.3 | 77.2 | 2.0 | 7.6 | - | 413.0 | 48.0 | 1,686.4 |
| Hyc32 | - | - | - | - | - | - | 12.2 | 2.9 | - | - | - | 9.3 | - | - | - | 24.5 |
| Hyc33 | 0.7 | 5.3 | - | - | - | 17.6 | 114.1 | 68.3 | 30.5 | 8.5 | - | 82.7 | 1.8 | 74.3 | 0.4 | 404.1 |
| Hyc34 | 10.9 | 91.6 | 11.1 | - | - | 6.9 | 1,948.6 | 494.2 | 181.9 | 144.6 | 20.0 | 135.4 | - | 367.8 | 844.7 | 4,257.7 |
| Hyc35 | - | 8.0 | - | - | - | 9.1 | 436.1 | 353.8 | 54.0 | 41.6 | 4.2 | 183.9 | 1.6 | 222.4 | 46.7 | 1,361.5 |
| Hyc36 | 1.1 | 76.7 | 3.1 | - | - | 14.0 | 1,357.3 | 329.6 | 153.2 | 43.4 | 2.7 | 191.7 | 2.0 | 165.5 | 386.7 | 2,727.0 |
| Hyc37 | 69.6 | 88.1 | 15.6 | 5.3 | - | - | 291.1 | 85.4 | 60.7 | 1.8 | 16.0 | 1.6 | - | 39.8 | 323.4 | 998.3 |
| Hyc38 | 80.1 | 97.6 | 24.7 | - | - | - | 625.8 | 21.8 | 38.5 | 27.1 | 6.4 | 25.4 | 3.1 | 106.3 | 684.8 | 1,741.6 |
| Hyc39 | 121.6 | 40.0 | 13.1 | - | - | - | 792.2 | 52.5 | 60.9 | 12.0 | 22.9 | 12.9 | - | 71.4 | 479.9 | 1,679.5 |
| Hyc4 | 1.3 | 36.5 | 6.4 | 2.7 | - | - | 315.1 | 627.4 | 70.9 | - | 8.0 | 17.1 | - | 126.5 | 12.9 | 1,224.9 |
| Hyc40 | 46.9 | 125.4 | 28.9 | 2.9 | - | 6.2 | 1,279.4 | 40.9 | 82.7 | 17.6 | 33.8 | 22.0 | - | 79.4 | 558.0 | 2,324.2 |
| Hyc41 | 35.1 | 223.1 | 31.6 | 9.6 | - | 5.6 | 1,423.3 | 78.5 | 107.4 | 48.7 | - | 3.3 | - | 93.0 | 291.1 | 2,350.3 |
| Hyc42 | 1.1 | 27.4 | - | - | - | - | 261.3 | 279.8 | 100.5 | 19.6 | - | 163.9 | - | 40.9 | 148.3 | 1,042.8 |
| Hyc43 | 2.7 | 70.3 | 2.9 | 2.9 | 4.9 | 65.8 | 1,371.1 | 463.5 | 233.5 | 52.3 | 3.3 | 87.8 | - | 342.0 | 411.0 | 3,114.0 |
| Hyc44 | 8.2 | 202.8 | 76.3 | 19.8 | 15.8 | - | 1,371.1 | 123.9 | 162.8 | 48.9 | 25.6 | 33.8 | - | 153.0 | 753.9 | 2,995.9 |
| Hyc45 | - | 11.6 | 3.1 | 0.4 | - | - | 217.1 | 26.7 | 20.0 | 2.7 | - | 14.9 | - | 2.0 | 56.5 | 354.9 |
| Hyc46 | 1.8 | 313.4 | 52.5 | 23.8 | 3.1 | - | 1,004.1 | 38.3 | 46.9 | 6.2 | - | - | - | 21.6 | 94.1 | 1,605.7 |
| Hyc47 | - | 87.2 | 80.7 | 17.1 | 7.1 | - | 450.1 | 54.0 | 41.8 | 9.6 | 6.2 | 26.5 | 1.6 | 33.6 | 53.2 | 868.7 |
| Hyc48 | 5.6 | 130.3 | 137.2 | 20.9 | 5.1 | 21.3 | 857.6 | 42.7 | 60.9 | 32.9 | 20.9 | 33.8 | - | 123.0 | 431.4 | 1,923.7 |
| Hyc49 | - | 129.2 | 255.1 | 152.8 | 110.1 | - | 116.1 | 12.0 | 12.5 | 1.3 | - | - | - | 10.7 | 20.2 | 820.0 |
| Hyc5 | 1.6 | 3.8 | - | - | - | - | 64.0 | 303.1 | 6.7 | - | - | 23.1 | - | 28.2 | - | 423.9 |
| Hyc50 | - | 110.3 | 204.2 | 71.8 | 26.9 | 5.1 | 599.6 | 34.9 | 33.8 | 5.1 | 3.6 | - | - | 61.2 | 107.2 | 1,263.6 |
| Hyc51 | 9.1 | 33.4 | 6.7 | 1.3 | - | - | 1,195.4 | 371.6 | 161.5 | 40.0 | - | 62.3 | - | 149.2 | 356.5 | 2,387.0 |
| Hyc52 | 2.2 | 62.7 | 6.7 | 0.7 | - | 2.9 | 1,005.2 | 374.7 | 143.9 | 44.5 | - | 8.7 | - | 114.3 | 461.5 | 2,227.9 |
| Hyc53 | 6.4 | 133.9 | 0.9 | 1.3 | - | 2.7 | 1,227.8 | 294.2 | 248.2 | 82.1 | 10.9 | 6.9 | - | 216.8 | 532.2 | 2,764.4 |
| Hyc54 | 1.3 | 26.2 | 2.7 | - | - | - | 474.1 | 103.4 | 42.3 | 83.8 | 3.6 | 25.4 | - | 197.3 | 35.4 | 995.4 |
| Hyc55 | 11.3 | 78.3 | 9.3 | 0.7 | - | - | 910.0 | 383.9 | 116.3 | 56.3 | 21.6 | 2.7 | - | 173.5 | 141.2 | 1,905.0 |
| Hyc56 | 1.1 | 13.6 | - | - | - | 32.0 | 280.2 | 64.0 | 26.9 | 2.9 | 15.3 | 125.0 | - | 129.2 | - | 688.1 |
| Hyc57 | 9.6 | 80.1 | 9.1 | - | - | 1.1 | 743.7 | 135.4 | 63.6 | 10.5 | 59.2 | 75.4 | - | 242.4 | 28.7 | 1,458.7 |
| Hyc58 | 118.1 | 96.1 | 44.7 | 41.6 | 18.9 | 7.3 | 1,219.4 | 460.6 | 177.7 | 86.1 | 5.3 | 80.1 | 2.9 | 386.5 | 90.5 | 2,835.8 |
| Hyc59 | 1.6 | 39.1 | - | - | - | - | 498.6 | 190.1 | 78.7 | 45.8 | 10.2 | 111.0 | - | 181.5 | 12.5 | 1,169.1 |
| Hyc6 | - | 16.9 | - | - | - | 1.1 | 368.7 | 505.9 | 54.9 | 9.6 | - | 31.8 | - | 18.7 | 12.2 | 1,019.9 |
| Hyc60 | - | 101.6 | 4.2 | - | - | 19.8 | 1,445.3 | 412.1 | 231.7 | 36.0 | 15.8 | 83.6 | - | 562.0 | 51.4 | 2,963.6 |
| Hyc61 | - | 25.1 | - | - | - | - | 601.6 | 264.2 | 128.8 | 47.4 | 38.5 | 30.7 | - | 350.7 | 90.7 | 1,577.7 |
| Hyc62 | 2.7 | 26.0 | - | - | - | - | 535.5 | 352.3 | 81.0 | 15.1 | 5.1 | 32.2 | - | 205.5 | 37.4 | 1,292.8 |
| Hyc63 | - | 34.0 | - | - | - | - | 992.5 | 185.3 | 81.6 | 34.5 | - | 60.5 | - | 146.3 | 15.6 | 1,550.3 |
| Hyc64 | 1.1 | 75.4 | 7.3 | - | - | 12.2 | 963.9 | 197.3 | 122.1 | 89.6 | 40.7 | 22.7 | - | 216.4 | 245.1 | 1,993.8 |

| Sub-watershed | Open Water | Developed, Open Space | Developed, Low Intensity | Developed, Medium Intensity | Developed, High Intensity | Barren Land | Deciduous Forest | Evergreen Forest | Mixed Forest | Shrub /Scrub | Cultivated Crops | Woody Wetlands | Emergent Herbaceous Wetlands | Pasture | Hay | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Hyc65 | 6.4 | 89.4 | 1.6 | 1.6 | - | 5.1 | 907.6 | 529.7 | 135.0 | 70.7 | 8.2 | 31.4 | - | 232.4 | 260.0 | 2,279.1 |
| Hyc66 | 1.1 | 67.8 | 2.7 | - | - | - | 634.5 | 115.0 | 68.3 | 33.4 | 5.6 | 40.3 | - | 143.4 | 304.9 | 1,416.9 |
| Hyc67 | - | 9.8 | 2.9 | - | - | - | 503.9 | 216.8 | 54.7 | 34.7 | 15.8 | 7.3 | - | 51.2 | 83.0 | 980.1 |
| Hyc68 | 3.8 | 68.9 | 5.3 | - | - | - | 828.9 | 86.5 | 53.4 | 87.2 | 8.0 | 1.1 | - | 104.3 | 447.5 | 1,694.9 |
| Hyc69 | 4.0 | 89.6 | - | - | - | 11.8 | 790.4 | 332.0 | 186.4 | 26.2 | 38.0 | 26.2 | - | 557.3 | 100.3 | 2,162.3 |
| Hyc7 | 2.7 | 54.7 | - | - | - | 50.5 | 766.8 | 535.5 | 199.9 | 35.6 | 0.7 | 67.6 | - | 231.5 | 62.7 | 2,008.2 |
| Hyc70 | - | 34.0 | - | - | - | 127.4 | 427.2 | 391.6 | 77.6 | 2.7 | 7.3 | 31.8 | - | 340.3 | - | 1,418.7 |
| Hyc71 | 2.4 | 57.2 | 0.2 | - | - | - | 640.3 | 260.0 | 109.4 | 8.7 | 23.1 | 14.5 | - | 286.4 | - | 1,384.9 |
| Hyc8 | - | 80.7 | - | - | - | 2.9 | 1,111.8 | 717.9 | 234.4 | 82.7 | 8.2 | 154.1 | - | 384.3 | 0.4 | 2,777.5 |
| Hyc9 | 22.5 | 32.7 | 1.3 | - | - | 26.5 | 642.5 | 514.2 | 107.2 | 80.3 | - | 101.6 | - | 187.9 | - | 1,703.3 |
| LBC1 | - | - | - | - | - | - | 2.0 | 7.1 | - | - | - | 4.0 | - | - | - | 13.1 |
| LBC10 | - | 8.7 | 3.6 | - | - | - | 37.4 | 8.5 | 2.7 | 1.1 | 1.6 | 27.4 | - | 62.9 | 33.1 | 186.8 |
| LBC11 | 2.7 | 30.5 | 10.0 | 3.3 | - | 12.7 | 47.8 | 17.3 | 9.1 | 8.5 | 15.8 | 3.1 | - | 155.2 | 130.8 | 446.8 |
| LBC12 | - | 4.2 | 0.7 | - | - | - | 36.9 | 12.5 | 5.6 | 1.8 | 5.3 | 10.0 | - | 66.7 | 51.6 | 195.3 |
| LBC13 | - | 7.3 | 0.9 | - | - | - | 20.9 | 11.3 | 9.3 | 1.8 | - | 2.4 | - | 41.4 | 20.7 | 116.1 |
| LBC2 | 2.0 | - | - | - | - | - | 11.3 | 5.3 | - | 1.1 | - | 7.3 | - | 6.7 | 1.3 | 35.1 |
| LBC3 | - | 3.1 | - | - | - | - | 4.0 | 1.8 | - | - | - | 5.3 | - | 7.6 | 2.9 | 24.7 |
| LBC4 | - | 33.8 | 26.5 | 2.4 | - | 19.1 | 18.0 | 10.5 | 7.1 | 1.3 | - | 22.7 | - | 35.1 | 8.7 | 185.3 |
| LBC5 | - | 5.6 | - | - | - | 33.8 | 65.2 | 12.9 | 8.9 | 3.6 | 6.0 | 13.8 | - | 82.7 | 39.1 | 271.5 |
| LBC6 | - | 20.7 | 3.6 | - | - | - | 134.5 | 45.6 | 21.6 | 4.0 | - | 2.4 | - | 75.4 | 48.5 | 356.3 |
| LBC7 | - | 13.6 | 6.7 | - | - | - | 85.4 | 1.3 | 1.1 | - | 0.2 | 2.2 | - | 81.4 | 53.4 | 245.3 |
| LBC8 | 1.1 | 15.8 | 1.6 | - | - | - | 17.3 | 8.0 | 8.5 | - | - | 2.9 | - | 60.7 | 43.4 | 159.2 |
| LBC9 | 2.4 | 22.0 | 4.4 | 1.8 | - | - | 20.9 | 25.4 | 10.9 | - | - | - | - | 43.1 | 41.1 | 172.1 |
| Total | 791.3 | 6,325.3 | 1,350.2 | 407.9 | 193.3 | 763.5 | 66,185.1 | 22,676.2 | 8,917.6 | 4,118.7 | 1,130.9 | 4,869.6 | 24.2 | 24,125.1 | 14,874 | 156,488 |

# APPENDIX B. LIVESTOCK, SEPTIC, PET, AND WILDLIFE INVENTORY BY SUB-WATERSHED

*Table B.1. Livestock Inventory by Sub-watershed*

| Sub-watershed | Number of Cattle | Number of Goats | Number of Sheep | Number of Horse |
|---|---|---|---|---|
| Aarons_1 | 136 | 6 | 0 | 5 |
| Aarons_10 | 52 | 2 | 0 | 2 |
| Aarons_11 | 124 | 5 | 0 | 5 |
| Aarons_12 | 34 | 2 | 0 | 1 |
| Aarons_13 | 12 | 1 | 0 | 0 |
| Aarons_14 | 36 | 2 | 0 | 1 |
| Aarons_15 | 95 | 5 | 1 | 4 |
| Aarons_16 | 80 | 3 | 0 | 3 |
| Aarons_17 | 21 | 1 | 0 | 1 |
| Aarons_18 | 36 | 2 | 0 | 2 |
| Aarons_19 | 69 | 6 | 4 | 7 |
| Aarons_2 | 1 | 0 | 0 | 0 |
| Aarons_20 | 58 | 4 | 1 | 4 |
| Aarons_21 | 7 | 1 | 0 | 1 |
| Aarons_22 | 16 | 1 | 1 | 2 |
| Aarons_23 | 9 | 1 | 1 | 1 |
| Aarons_24 | 8 | 1 | 0 | 1 |
| Aarons_25 | 74 | 10 | 5 | 8 |
| Aarons_26 | 32 | 11 | 3 | 4 |
| Aarons_27 | 28 | 3 | 2 | 3 |
| Aarons_28 | 35 | 10 | 3 | 4 |
| Aarons_29 | 16 | 6 | 1 | 2 |
| Aarons_3 | 25 | 1 | 0 | 1 |
| Aarons_30 | 26 | 2 | 2 | 3 |
| Aarons_31 | 10 | 3 | 1 | 1 |
| Aarons_32 | 0 | 0 | 0 | 0 |
| Aarons_33 | 5 | 1 | 0 | 1 |
| Aarons_34 | 75 | 7 | 4 | 8 |
| Aarons_35 | 49 | 5 | 3 | 5 |
| Aarons_36 | 26 | 2 | 2 | 3 |
| Aarons_37 | 27 | 3 | 2 | 3 |
| Aarons_38 | 67 | 2 | 0 | 2 |
| Aarons_39 | 79 | 3 | 0 | 3 |
| Aarons_4 | 15 | 1 | 0 | 1 |
| Aarons_40 | 126 | 4 | 0 | 4 |
| Aarons_5 | 120 | 6 | 1 | 5 |
| Aarons_6 | 30 | 2 | 0 | 1 |
| Aarons_7 | 71 | 4 | 0 | 3 |
| Aarons_8 | 103 | 6 | 1 | 5 |

| Sub-watershed | Number of Cattle | Number of Goats | Number of Sheep | Number of Horse |
|---|---|---|---|---|
| Aarons_9 | 4 | 0 | 0 | 0 |
| Beech_1 | 1 | 0 | 0 | 0 |
| Beech_10 | 64 | 2 | 0 | 2 |
| Beech_11 | 1 | 0 | 0 | 0 |
| Beech_12 | 55 | 2 | 0 | 2 |
| Beech_13 | 54 | 2 | 0 | 2 |
| Beech_14 | 27 | 1 | 0 | 1 |
| Beech_15 | 22 | 1 | 0 | 1 |
| Beech_2 | 2 | 0 | 0 | 0 |
| Beech_3 | 7 | 0 | 0 | 0 |
| Beech_4 | 0 | 0 | 0 | 0 |
| Beech_5 | 9 | 0 | 0 | 0 |
| Beech_6 | 36 | 1 | 0 | 1 |
| Beech_7 | 15 | 0 | 0 | 0 |
| Beech_8 | 60 | 2 | 0 | 2 |
| Beech_9 | 10 | 0 | 0 | 0 |
| Hyc1 | 52 | 3 | 0 | 2 |
| Hyc10 | 65 | 3 | 0 | 3 |
| Hyc11 | 11 | 1 | 0 | 0 |
| Hyc12 | 39 | 2 | 0 | 2 |
| Hyc13 | 82 | 4 | 0 | 4 |
| Hyc14 | 10 | 1 | 0 | 0 |
| Hyc15 | 16 | 1 | 0 | 1 |
| Hyc16 | 97 | 5 | 1 | 4 |
| Hyc17 | 50 | 3 | 0 | 2 |
| Hyc18 | 29 | 2 | 0 | 1 |
| Hyc19 | 22 | 1 | 0 | 1 |
| Hyc2 | 2 | 0 | 0 | 0 |
| Hyc20 | 59 | 3 | 0 | 3 |
| Hyc21 | 16 | 1 | 0 | 1 |
| Hyc22 | 0 | 0 | 0 | 0 |
| Hyc23 | 0 | 0 | 0 | 0 |
| Hyc24 | 91 | 5 | 1 | 4 |
| Hyc25 | 101 | 9 | 2 | 6 |
| Hyc26 | 56 | 8 | 2 | 4 |
| Hyc27 | 0 | 0 | 0 | 0 |
| Hyc28 | 30 | 4 | 1 | 2 |
| Hyc29 | 59 | 5 | 1 | 3 |
| Hyc3 | 81 | 4 | 0 | 3 |
| Hyc30 | 63 | 3 | 0 | 3 |

| Sub-watershed | Number of Cattle | Number of Goats | Number of Sheep | Number of Horse |
|---|---|---|---|---|
| Hyc31 | 68 | 4 | 1 | 3 |
| Hyc32 | 0 | 0 | 0 | 0 |
| Hyc33 | 14 | 5 | 1 | 2 |
| Hyc34 | 67 | 24 | 5 | 9 |
| Hyc35 | 41 | 14 | 3 | 6 |
| Hyc36 | 30 | 11 | 2 | 4 |
| Hyc37 | 7 | 3 | 1 | 1 |
| Hyc38 | 19 | 7 | 2 | 3 |
| Hyc39 | 13 | 5 | 1 | 2 |
| Hyc4 | 21 | 1 | 0 | 1 |
| Hyc40 | 14 | 5 | 1 | 2 |
| Hyc41 | 17 | 6 | 1 | 2 |
| Hyc42 | 7 | 3 | 1 | 1 |
| Hyc43 | 62 | 22 | 5 | 8 |
| Hyc44 | 28 | 10 | 2 | 4 |
| Hyc45 | 0 | 0 | 0 | 0 |
| Hyc46 | 4 | 1 | 0 | 1 |
| Hyc47 | 6 | 2 | 0 | 1 |
| Hyc48 | 22 | 8 | 2 | 3 |
| Hyc49 | 2 | 1 | 0 | 0 |
| Hyc5 | 5 | 0 | 0 | 0 |
| Hyc50 | 11 | 4 | 1 | 2 |
| Hyc51 | 27 | 10 | 2 | 4 |
| Hyc52 | 21 | 7 | 2 | 3 |
| Hyc53 | 40 | 14 | 3 | 5 |
| Hyc54 | 32 | 2 | 0 | 1 |
| Hyc55 | 31 | 9 | 2 | 4 |
| Hyc56 | 21 | 1 | 0 | 1 |
| Hyc57 | 40 | 2 | 0 | 2 |
| Hyc58 | 65 | 7 | 1 | 4 |
| Hyc59 | 30 | 2 | 0 | 1 |
| Hyc6 | 3 | 0 | 0 | 0 |
| Hyc60 | 92 | 5 | 1 | 4 |
| Hyc61 | 58 | 3 | 0 | 2 |
| Hyc62 | 34 | 2 | 0 | 1 |
| Hyc63 | 24 | 1 | 0 | 1 |
| Hyc64 | 38 | 10 | 2 | 4 |
| Hyc65 | 56 | 9 | 3 | 6 |
| Hyc66 | 36 | 8 | 3 | 4 |
| Hyc67 | 9 | 3 | 1 | 1 |

| Sub-watershed | Number of Cattle | Number of Goats | Number of Sheep | Number of Horse |
|---|---|---|---|---|
| Hyc68 | 19 | 7 | 2 | 3 |
| Hyc69 | 92 | 5 | 1 | 4 |
| Hyc7 | 38 | 2 | 0 | 2 |
| Hyc70 | 56 | 3 | 0 | 2 |
| Hyc71 | 47 | 2 | 0 | 2 |
| Hyc8 | 63 | 3 | 0 | 3 |
| Hyc9 | 31 | 2 | 0 | 1 |
| LBC1 | 0 | 0 | 0 | 0 |
| LBC10 | 20 | 1 | 0 | 1 |
| LBC11 | 50 | 2 | 0 | 2 |
| LBC12 | 21 | 1 | 0 | 1 |
| LBC13 | 13 | 0 | 0 | 0 |
| LBC2 | 2 | 0 | 0 | 0 |
| LBC3 | 2 | 0 | 0 | 0 |
| LBC4 | 11 | 0 | 0 | 0 |
| LBC5 | 27 | 1 | 0 | 1 |
| LBC6 | 24 | 1 | 0 | 1 |
| LBC7 | 26 | 1 | 0 | 1 |
| LBC8 | 20 | 1 | 0 | 1 |
| LBC9 | 14 | 0 | 0 | 0 |
| Total | 4,924 | 478 | 106 | 296 |

Table B.2. Septic System Inventory by Sub-watershed

| Sub-watershed | Number of Houses | Houses within 200 feet of stream | Number of Septic Systems | Number of Straight Pipes | Number of Septic Systems within 200 feet |
|---|---|---|---|---|---|
| Aarons_1 | 68 | 18 | 46 | 2 | 12 |
| Aarons_10 | 13 | 3 | 8 | 0 | 2 |
| Aarons_11 | 47 | 13 | 34 | 1 | 10 |
| Aarons_12 | 28 | 8 | 21 | 1 | 6 |
| Aarons_13 | 5 | 2 | 4 | 0 | 2 |
| Aarons_14 | 16 | 5 | 11 | 0 | 3 |
| Aarons_15 | 46 | 15 | 36 | 1 | 11 |
| Aarons_16 | 20 | 7 | 13 | 1 | 5 |
| Aarons_17 | 7 | 2 | 5 | 0 | 2 |
| Aarons_18 | 56 | 17 | 43 | 2 | 13 |
| Aarons_19 | 46 | 14 | 28 | 1 | 8 |
| Aarons_2 | 0 | 0 | 0 | 0 | 0 |
| Aarons_20 | 33 | 9 | 21 | 1 | 6 |
| Aarons_21 | 18 | 7 | 10 | 0 | 4 |
| Aarons_22 | 26 | 10 | 15 | 1 | 6 |
| Aarons_23 | 32 | 8 | 18 | 0 | 5 |
| Aarons_24 | 16 | 5 | 9 | 0 | 3 |
| Aarons_25 | 19 | 7 | 12 | 0 | 4 |
| Aarons_26 | 25 | 6 | 16 | 0 | 4 |
| Aarons_27 | 15 | 4 | 9 | 0 | 3 |
| Aarons_28 | 16 | 5 | 10 | 0 | 3 |
| Aarons_29 | 29 | 8 | 18 | 0 | 5 |
| Aarons_3 | 15 | 5 | 12 | 0 | 4 |
| Aarons_30 | 20 | 6 | 12 | 0 | 3 |
| Aarons_31 | 25 | 8 | 16 | 0 | 5 |
| Aarons_32 | 1 | 0 | 1 | 0 | 0 |
| Aarons_33 | 3 | 1 | 2 | 0 | 1 |
| Aarons_34 | 21 | 6 | 12 | 0 | 3 |
| Aarons_35 | 22 | 5 | 13 | 0 | 3 |
| Aarons_36 | 31 | 7 | 18 | 0 | 4 |
| Aarons_37 | 23 | 4 | 13 | 0 | 2 |
| Aarons_38 | 15 | 4 | 9 | 0 | 2 |
| Aarons_39 | 20 | 3 | 12 | 0 | 2 |
| Aarons_4 | 13 | 4 | 10 | 0 | 3 |
| Aarons_40 | 36 | 9 | 22 | 1 | 5 |
| Aarons_5 | 42 | 14 | 32 | 1 | 11 |
| Aarons_6 | 6 | 3 | 5 | 0 | 2 |
| Aarons_7 | 44 | 17 | 34 | 2 | 13 |

| Sub-watershed | Number of Houses | Houses within 200 feet of stream | Number of Septic Systems | Number of Straight Pipes | Number of Septic Systems within 200 feet |
|---|---|---|---|---|---|
| Aarons_8 | 73 | 22 | 56 | 2 | 17 |
| Aarons_9 | 1 | 0 | 1 | 0 | 0 |
| Beech_1 | 0 | 0 | 0 | 0 | 0 |
| Beech_10 | 18 | 5 | 18 | 5 | 5 |
| Beech_11 | 0 | 0 | 0 | 0 | 0 |
| Beech_12 | 11 | 3 | 11 | 3 | 3 |
| Beech_13 | 11 | 5 | 11 | 5 | 5 |
| Beech_14 | 3 | 1 | 3 | 1 | 1 |
| Beech_15 | 6 | 1 | 6 | 1 | 1 |
| Beech_2 | 3 | 1 | 3 | 1 | 1 |
| Beech_3 | 3 | 1 | 3 | 1 | 1 |
| Beech_4 | 0 | 0 | 0 | 0 | 0 |
| Beech_5 | 11 | 3 | 11 | 3 | 3 |
| Beech_6 | 8 | 2 | 8 | 2 | 2 |
| Beech_7 | 5 | 2 | 5 | 2 | 2 |
| Beech_8 | 11 | 2 | 11 | 2 | 2 |
| Beech_9 | 2 | 1 | 2 | 1 | 1 |
| Hyc1 | 50 | 15 | 39 | 1 | 12 |
| Hyc10 | 115 | 38 | 89 | 4 | 29 |
| Hyc11 | 7 | 3 | 5 | 0 | 2 |
| Hyc12 | 29 | 10 | 22 | 1 | 8 |
| Hyc13 | 97 | 30 | 75 | 3 | 23 |
| Hyc14 | 4 | 1 | 3 | 0 | 1 |
| Hyc15 | 13 | 5 | 10 | 0 | 4 |
| Hyc16 | 87 | 22 | 67 | 2 | 17 |
| Hyc17 | 21 | 6 | 16 | 1 | 4 |
| Hyc18 | 24 | 5 | 18 | 0 | 4 |
| Hyc19 | 15 | 5 | 12 | 0 | 4 |
| Hyc2 | 11 | 2 | 8 | 0 | 2 |
| Hyc20 | 33 | 8 | 26 | 1 | 6 |
| Hyc21 | 8 | 1 | 6 | 0 | 1 |
| Hyc22 | 0 | 0 | 0 | 0 | 0 |
| Hyc23 | 0 | 0 | 0 | 0 | 0 |
| Hyc24 | 27 | 9 | 21 | 1 | 7 |
| Hyc25 | 28 | 9 | 21 | 1 | 7 |
| Hyc26 | 16 | 4 | 11 | 0 | 3 |
| Hyc27 | 0 | 0 | 0 | 0 | 0 |
| Hyc28 | 9 | 2 | 6 | 0 | 2 |
| Hyc29 | 8 | 2 | 6 | 0 | 2 |

| Sub-watershed | Number of Houses | Houses within 200 feet of stream | Number of Septic Systems | Number of Straight Pipes | Number of Septic Systems within 200 feet |
|---|---|---|---|---|---|
| Hyc3 | 47 | 13 | 36 | 1 | 10 |
| Hyc30 | 18 | 4 | 14 | 0 | 3 |
| Hyc31 | 14 | 3 | 10 | 0 | 2 |
| Hyc32 | 0 | 0 | 0 | 0 | 0 |
| Hyc33 | 0 | 0 | 0 | 0 | 0 |
| Hyc34 | 124 | 34 | 79 | 2 | 22 |
| Hyc35 | 11 | 4 | 7 | 0 | 2 |
| Hyc36 | 77 | 21 | 49 | 1 | 13 |
| Hyc37 | 118 | 33 | 75 | 2 | 21 |
| Hyc38 | 201 | 57 | 129 | 3 | 37 |
| Hyc39 | 99 | 23 | 63 | 1 | 15 |
| Hyc4 | 18 | 6 | 14 | 1 | 5 |
| Hyc40 | 184 | 48 | 118 | 2 | 31 |
| Hyc41 | 367 | 96 | 235 | 5 | 61 |
| Hyc42 | 9 | 2 | 6 | 0 | 2 |
| Hyc43 | 79 | 16 | 51 | 1 | 10 |
| Hyc44 | 488 | 116 | 312 | 6 | 74 |
| Hyc45 | 51 | 11 | 32 | 1 | 7 |
| Hyc46 | 436 | 96 | 279 | 5 | 61 |
| Hyc47 | 484 | 87 | 310 | 4 | 56 |
| Hyc48 | 779 | 187 | 498 | 9 | 120 |
| Hyc49 | 1037 | 107 | 664 | 5 | 68 |
| Hyc5 | 3 | 1 | 2 | 0 | 1 |
| Hyc50 | 974 | 177 | 623 | 9 | 113 |
| Hyc51 | 36 | 10 | 23 | 0 | 6 |
| Hyc52 | 27 | 7 | 17 | 0 | 4 |
| Hyc53 | 84 | 16 | 54 | 1 | 11 |
| Hyc54 | 4 | 1 | 3 | 0 | 1 |
| Hyc55 | 21 | 6 | 13 | 0 | 4 |
| Hyc56 | 11 | 4 | 9 | 0 | 3 |
| Hyc57 | 28 | 8 | 21 | 1 | 6 |
| Hyc58 | 34 | 10 | 25 | 1 | 8 |
| Hyc59 | 15 | 5 | 11 | 0 | 4 |
| Hyc6 | 15 | 4 | 12 | 0 | 3 |
| Hyc60 | 65 | 22 | 50 | 2 | 17 |
| Hyc61 | 16 | 5 | 13 | 1 | 4 |
| Hyc62 | 11 | 3 | 9 | 0 | 3 |
| Hyc63 | 21 | 6 | 16 | 1 | 4 |
| Hyc64 | 70 | 20 | 46 | 1 | 13 |

| Sub-watershed | Number of Houses | Houses within 200 feet of stream | Number of Septic Systems | Number of Straight Pipes | Number of Septic Systems within 200 feet |
|---|---|---|---|---|---|
| Hyc65 | 58 | 17 | 39 | 1 | 12 |
| Hyc66 | 41 | 11 | 26 | 1 | 7 |
| Hyc67 | 25 | 6 | 16 | 0 | 4 |
| Hyc68 | 67 | 23 | 43 | 1 | 15 |
| Hyc69 | 27 | 8 | 21 | 1 | 6 |
| Hyc7 | 40 | 10 | 31 | 1 | 8 |
| Hyc70 | 11 | 3 | 8 | 0 | 2 |
| Hyc71 | 31 | 6 | 24 | 1 | 5 |
| Hyc8 | 73 | 17 | 56 | 2 | 13 |
| Hyc9 | 54 | 15 | 41 | 1 | 11 |
| LBC1 | 1 | 1 | 1 | 1 | 1 |
| LBC10 | 5 | 3 | 5 | 3 | 3 |
| LBC11 | 14 | 6 | 14 | 6 | 6 |
| LBC12 | 5 | 1 | 5 | 1 | 1 |
| LBC13 | 4 | 1 | 4 | 1 | 1 |
| LBC2 | 3 | 1 | 3 | 1 | 1 |
| LBC3 | 1 | 1 | 1 | 1 | 1 |
| LBC4 | 83 | 30 | 83 | 30 | 30 |
| LBC5 | 7 | 2 | 7 | 2 | 2 |
| LBC6 | 10 | 2 | 10 | 2 | 2 |
| LBC7 | 6 | 2 | 6 | 2 | 2 |
| LBC8 | 6 | 3 | 6 | 3 | 3 |
| LBC9 | 7 | 3 | 7 | 3 | 3 |

Table B.3. Pet Inventory by Sub-watershed

| Sub-watershed | Number of Houses | Number of Dogs | Number of Cats |
|---|---|---|---|
| Aarons_1 | 68 | 40 | 43 |
| Aarons_10 | 13 | 7 | 8 |
| Aarons_11 | 47 | 28 | 30 |
| Aarons_12 | 28 | 16 | 18 |
| Aarons_13 | 5 | 3 | 3 |
| Aarons_14 | 16 | 9 | 10 |
| Aarons_15 | 46 | 27 | 30 |
| Aarons_16 | 20 | 11 | 13 |
| Aarons_17 | 7 | 4 | 4 |
| Aarons_18 | 56 | 33 | 36 |
| Aarons_19 | 46 | 27 | 30 |
| Aarons_2 | 0 | 0 | 0 |
| Aarons_20 | 33 | 19 | 21 |
| Aarons_21 | 18 | 10 | 11 |
| Aarons_22 | 26 | 15 | 16 |
| Aarons_23 | 32 | 18 | 20 |
| Aarons_24 | 16 | 9 | 10 |
| Aarons_25 | 19 | 11 | 12 |
| Aarons_26 | 25 | 15 | 16 |
| Aarons_27 | 15 | 9 | 9 |
| Aarons_28 | 16 | 9 | 10 |
| Aarons_29 | 29 | 17 | 18 |
| Aarons_3 | 15 | 9 | 10 |
| Aarons_30 | 20 | 12 | 13 |
| Aarons_31 | 25 | 15 | 16 |
| Aarons_32 | 1 | 1 | 1 |
| Aarons_33 | 3 | 2 | 2 |
| Aarons_34 | 21 | 12 | 14 |
| Aarons_35 | 22 | 13 | 14 |
| Aarons_36 | 31 | 18 | 20 |
| Aarons_37 | 23 | 13 | 15 |
| Aarons_38 | 15 | 9 | 10 |
| Aarons_39 | 20 | 12 | 13 |
| Aarons_4 | 13 | 8 | 8 |
| Aarons_40 | 36 | 21 | 23 |
| Aarons_5 | 42 | 24 | 26 |
| Aarons_6 | 6 | 3 | 4 |
| Aarons_7 | 44 | 26 | 28 |
| Aarons_8 | 73 | 43 | 47 |
| Aarons_9 | 1 | 1 | 1 |

| Sub-watershed | Number of Houses | Number of Dogs | Number of Cats |
|---|---|---|---|
| Beech_1 | 0 | 0 | 0 |
| Beech_10 | 18 | 11 | 12 |
| Beech_11 | 0 | 0 | 0 |
| Beech_12 | 11 | 7 | 7 |
| Beech_13 | 11 | 7 | 7 |
| Beech_14 | 3 | 1 | 2 |
| Beech_15 | 6 | 3 | 4 |
| Beech_2 | 3 | 2 | 2 |
| Beech_3 | 3 | 2 | 2 |
| Beech_4 | 0 | 0 | 0 |
| Beech_5 | 11 | 7 | 7 |
| Beech_6 | 8 | 5 | 5 |
| Beech_7 | 5 | 3 | 3 |
| Beech_8 | 11 | 6 | 7 |
| Beech_9 | 2 | 1 | 2 |
| Hyc1 | 50 | 29 | 32 |
| Hyc10 | 115 | 67 | 73 |
| Hyc11 | 7 | 4 | 4 |
| Hyc12 | 29 | 17 | 19 |
| Hyc13 | 97 | 57 | 62 |
| Hyc14 | 4 | 2 | 2 |
| Hyc15 | 13 | 7 | 8 |
| Hyc16 | 87 | 51 | 56 |
| Hyc17 | 21 | 12 | 13 |
| Hyc18 | 24 | 14 | 15 |
| Hyc19 | 15 | 9 | 10 |
| Hyc2 | 11 | 6 | 7 |
| Hyc20 | 33 | 19 | 21 |
| Hyc21 | 8 | 5 | 5 |
| Hyc22 | 0 | 0 | 0 |
| Hyc23 | 0 | 0 | 0 |
| Hyc24 | 27 | 16 | 17 |
| Hyc25 | 28 | 17 | 18 |
| Hyc26 | 16 | 9 | 10 |
| Hyc27 | 0 | 0 | 0 |
| Hyc28 | 9 | 5 | 6 |
| Hyc29 | 8 | 5 | 5 |
| Hyc3 | 47 | 27 | 30 |
| Hyc30 | 18 | 11 | 12 |
| Hyc31 | 14 | 8 | 9 |

| Sub-watershed | Number of Houses | Number of Dogs | Number of Cats |
|---|---|---|---|
| Hyc32 | 0 | 0 | 0 |
| Hyc33 | 0 | 0 | 0 |
| Hyc34 | 124 | 72 | 79 |
| Hyc35 | 11 | 6 | 7 |
| Hyc36 | 77 | 45 | 49 |
| Hyc37 | 118 | 69 | 75 |
| Hyc38 | 201 | 118 | 129 |
| Hyc39 | 99 | 58 | 63 |
| Hyc4 | 18 | 11 | 12 |
| Hyc40 | 184 | 108 | 118 |
| Hyc41 | 367 | 214 | 234 |
| Hyc42 | 9 | 6 | 6 |
| Hyc43 | 79 | 46 | 50 |
| Hyc44 | 488 | 285 | 311 |
| Hyc45 | 51 | 30 | 32 |
| Hyc46 | 436 | 255 | 278 |
| Hyc47 | 484 | 283 | 309 |
| Hyc48 | 779 | 455 | 497 |
| Hyc49 | 1037 | 606 | 662 |
| Hyc5 | 3 | 2 | 2 |
| Hyc50 | 974 | 569 | 621 |
| Hyc51 | 36 | 21 | 23 |
| Hyc52 | 27 | 16 | 17 |
| Hyc53 | 84 | 49 | 54 |
| Hyc54 | 4 | 2 | 2 |
| Hyc55 | 21 | 12 | 13 |
| Hyc56 | 11 | 7 | 7 |
| Hyc57 | 28 | 16 | 18 |
| Hyc58 | 34 | 20 | 22 |
| Hyc59 | 15 | 9 | 9 |
| Hyc6 | 15 | 9 | 10 |
| Hyc60 | 65 | 38 | 41 |
| Hyc61 | 16 | 10 | 10 |
| Hyc62 | 11 | 7 | 7 |
| Hyc63 | 21 | 12 | 13 |
| Hyc64 | 70 | 41 | 45 |
| Hyc65 | 58 | 34 | 37 |
| Hyc66 | 41 | 24 | 26 |
| Hyc67 | 25 | 14 | 16 |
| Hyc68 | 67 | 39 | 43 |

| Sub-watershed | Number of Houses | Number of Dogs | Number of Cats |
|---|---|---|---|
| Hyc69 | 27 | 16 | 17 |
| Hyc7 | 40 | 23 | 26 |
| Hyc70 | 11 | 6 | 7 |
| Hyc71 | 31 | 18 | 20 |
| Hyc8 | 73 | 43 | 47 |
| Hyc9 | 54 | 31 | 34 |
| LBC1 | 1 | 1 | 1 |
| LBC10 | 5 | 3 | 3 |
| LBC11 | 14 | 8 | 9 |
| LBC12 | 5 | 3 | 3 |
| LBC13 | 4 | 2 | 2 |
| LBC2 | 3 | 2 | 2 |
| LBC3 | 1 | 1 | 1 |
| LBC4 | 83 | 48 | 53 |
| LBC5 | 7 | 4 | 4 |
| LBC6 | 10 | 6 | 7 |
| LBC7 | 6 | 4 | 4 |
| LBC8 | 6 | 4 | 4 |
| LBC9 | 7 | 4 | 5 |

Table B.4. Wildlife Inventory by Sub-watershed

| Sub-watershed | Deer | Raccoon | Muskrat | Beaver | Wild Turkey | Goose |
|---|---|---|---|---|---|---|
| Aarons_1 | 116 | 88 | 62 | 19 | 8 | 29 |
| Aarons_10 | 25 | 14 | 12 | 4 | 2 | 5 |
| Aarons_11 | 89 | 53 | 48 | 14 | 6 | 21 |
| Aarons_12 | 37 | 21 | 25 | 8 | 3 | 9 |
| Aarons_13 | 11 | 8 | 19 | 6 | 1 | 4 |
| Aarons_14 | 32 | 22 | 29 | 9 | 3 | 9 |
| Aarons_15 | 71 | 36 | 35 | 11 | 4 | 15 |
| Aarons_16 | 51 | 30 | 34 | 10 | 4 | 13 |
| Aarons_17 | 17 | 11 | 14 | 4 | 1 | 5 |
| Aarons_18 | 39 | 26 | 19 | 6 | 3 | 9 |
| Aarons_19 | 57 | 41 | 49 | 15 | 5 | 16 |
| Aarons_2 | 1 | 1 | 5 | 1 | 0 | 1 |
| Aarons_20 | 63 | 45 | 53 | 16 | 5 | 18 |
| Aarons_21 | 26 | 18 | 31 | 9 | 2 | 8 |
| Aarons_22 | 22 | 15 | 19 | 6 | 2 | 6 |
| Aarons_23 | 28 | 20 | 23 | 7 | 2 | 8 |
| Aarons_24 | 27 | 21 | 21 | 6 | 2 | 8 |
| Aarons_25 | 75 | 50 | 49 | 15 | 5 | 19 |
| Aarons_26 | 75 | 56 | 41 | 12 | 5 | 19 |
| Aarons_27 | 63 | 51 | 42 | 13 | 5 | 17 |
| Aarons_28 | 60 | 41 | 38 | 11 | 4 | 15 |
| Aarons_29 | 58 | 31 | 38 | 11 | 4 | 14 |
| Aarons_3 | 31 | 22 | 16 | 5 | 2 | 7 |
| Aarons_30 | 58 | 48 | 41 | 12 | 5 | 16 |
| Aarons_31 | 45 | 27 | 36 | 11 | 3 | 12 |
| Aarons_32 | 4 | 4 | 9 | 3 | 1 | 2 |
| Aarons_33 | 20 | 18 | 20 | 6 | 2 | 7 |
| Aarons_34 | 96 | 72 | 58 | 17 | 7 | 25 |
| Aarons_35 | 31 | 22 | 24 | 7 | 2 | 9 |
| Aarons_36 | 48 | 40 | 44 | 13 | 4 | 15 |
| Aarons_37 | 34 | 27 | 30 | 9 | 3 | 10 |
| Aarons_38 | 30 | 16 | 26 | 8 | 2 | 8 |
| Aarons_39 | 45 | 30 | 28 | 8 | 3 | 11 |
| Aarons_4 | 26 | 18 | 18 | 5 | 2 | 7 |
| Aarons_40 | 70 | 47 | 50 | 15 | 5 | 19 |
| Aarons_5 | 105 | 61 | 50 | 15 | 7 | 23 |
| Aarons_6 | 24 | 9 | 20 | 6 | 2 | 6 |
| Aarons_7 | 80 | 53 | 36 | 11 | 5 | 18 |
| Aarons_8 | 100 | 66 | 49 | 15 | 7 | 23 |

| Sub-watershed | Deer | Raccoon | Muskrat | Beaver | Wild Turkey | Goose |
|---|---|---|---|---|---|---|
| Aarons_9 | 4 | 3 | 8 | 2 | 0 | 2 |
| Beech_1 | 2 | 1 | 2 | 1 | 1 | 1 |
| Beech_10 | 19 | 7 | 29 | 9 | 12 | 9 |
| Beech_11 | 1 | 1 | 4 | 1 | 1 | 1 |
| Beech_12 | 25 | 14 | 26 | 8 | 13 | 11 |
| Beech_13 | 17 | 7 | 16 | 5 | 8 | 7 |
| Beech_14 | 9 | 4 | 13 | 4 | 6 | 4 |
| Beech_15 | 22 | 14 | 19 | 6 | 11 | 9 |
| Beech_2 | 3 | 4 | 5 | 2 | 3 | 2 |
| Beech_3 | 10 | 9 | 14 | 4 | 7 | 5 |
| Beech_4 | - | 1 | 2 | 1 | 1 | 1 |
| Beech_5 | 14 | 13 | 10 | 3 | 7 | 6 |
| Beech_6 | 20 | 12 | 25 | 8 | 12 | 10 |
| Beech_7 | 14 | 10 | 8 | 2 | 6 | 5 |
| Beech_8 | 25 | 13 | 27 | 8 | 13 | 11 |
| Beech_9 | 7 | 5 | 7 | 2 | 4 | 3 |
| Hyc1 | 64 | 54 | 97 | 29 | 5 | 14 |
| Hyc10 | 78 | 59 | 134 | 40 | 6 | 18 |
| Hyc11 | 19 | 13 | 85 | 26 | 3 | 8 |
| Hyc12 | 87 | 77 | 70 | 21 | 5 | 15 |
| Hyc13 | 92 | 63 | 98 | 29 | 6 | 16 |
| Hyc14 | 16 | 13 | 60 | 18 | 2 | 6 |
| Hyc15 | 12 | 8 | 34 | 10 | 1 | 4 |
| Hyc16 | 82 | 54 | 143 | 43 | 6 | 19 |
| Hyc17 | 50 | 33 | 66 | 20 | 3 | 10 |
| Hyc18 | 19 | 14 | 58 | 17 | 2 | 6 |
| Hyc19 | 22 | 15 | 47 | 14 | 2 | 6 |
| Hyc2 | 25 | 25 | 35 | 11 | 2 | 5 |
| Hyc20 | 70 | 47 | 94 | 28 | 5 | 14 |
| Hyc21 | 10 | 6 | 33 | 10 | 1 | 3 |
| Hyc22 | 1 | 2 | 16 | 5 | 0 | 1 |
| Hyc23 | 6 | 11 | 44 | 13 | 1 | 4 |
| Hyc24 | 90 | 71 | 194 | 58 | 8 | 24 |
| Hyc25 | 100 | 82 | 194 | 58 | 9 | 25 |
| Hyc26 | 64 | 49 | 153 | 46 | 6 | 18 |
| Hyc27 | 0 | 1 | 10 | 3 | 0 | 1 |
| Hyc28 | 39 | 29 | 65 | 20 | 3 | 9 |
| Hyc29 | 62 | 44 | 99 | 30 | 5 | 13 |
| Hyc3 | 74 | 50 | 107 | 32 | 5 | 15 |
| Hyc30 | 75 | 51 | 69 | 21 | 4 | 12 |

| Sub-watershed | Deer | Raccoon | Muskrat | Beaver | Wild Turkey | Goose |
|---|---|---|---|---|---|---|
| Hyc31 | 77 | 54 | 86 | 26 | 5 | 14 |
| Hyc32 | 1 | 1 | 13 | 4 | 0 | 1 |
| Hyc33 | 14 | 14 | 73 | 22 | 2 | 7 |
| Hyc34 | 188 | 139 | 333 | 100 | 15 | 44 |
| Hyc35 | 55 | 47 | 107 | 32 | 5 | 14 |
| Hyc36 | 115 | 89 | 220 | 66 | 10 | 28 |
| Hyc37 | 40 | 24 | 60 | 18 | 3 | 8 |
| Hyc38 | 73 | 39 | 75 | 23 | 4 | 12 |
| Hyc39 | 71 | 49 | 38 | 11 | 3 | 10 |
| Hyc4 | 55 | 37 | 33 | 10 | 3 | 8 |
| Hyc40 | 100 | 71 | 230 | 69 | 9 | 27 |
| Hyc41 | 98 | 79 | 243 | 73 | 10 | 28 |
| Hyc42 | 40 | 39 | 81 | 24 | 4 | 11 |
| Hyc43 | 139 | 100 | 163 | 49 | 9 | 26 |
| Hyc44 | 127 | 81 | 75 | 23 | 6 | 18 |
| Hyc45 | 15 | 13 | 49 | 15 | 2 | 5 |
| Hyc46 | 60 | 52 | 156 | 47 | 6 | 18 |
| Hyc47 | 35 | 28 | 91 | 27 | 4 | 10 |
| Hyc48 | 82 | 49 | 48 | 14 | 4 | 11 |
| Hyc49 | 27 | 7 | 125 | 38 | 4 | 11 |
| Hyc5 | 19 | 18 | 46 | 14 | 2 | 6 |
| Hyc50 | 53 | 32 | 116 | 35 | 5 | 14 |
| Hyc51 | 107 | 80 | 100 | 30 | 6 | 18 |
| Hyc52 | 101 | 69 | 87 | 26 | 6 | 16 |
| Hyc53 | 122 | 85 | 142 | 43 | 8 | 23 |
| Hyc54 | 45 | 37 | 68 | 20 | 3 | 10 |
| Hyc55 | 85 | 70 | 80 | 24 | 5 | 15 |
| Hyc56 | 26 | 17 | 85 | 26 | 3 | 9 |
| Hyc57 | 61 | 47 | 86 | 26 | 4 | 13 |
| Hyc58 | 116 | 97 | 86 | 26 | 6 | 19 |
| Hyc59 | 48 | 43 | 118 | 35 | 5 | 14 |
| Hyc6 | 46 | 46 | 81 | 24 | 4 | 11 |
| Hyc60 | 131 | 104 | 76 | 23 | 7 | 19 |
| Hyc61 | 72 | 49 | 102 | 31 | 5 | 15 |
| Hyc62 | 58 | 46 | 56 | 17 | 3 | 10 |
| Hyc63 | 69 | 57 | 170 | 51 | 7 | 20 |
| Hyc64 | 88 | 59 | 147 | 44 | 7 | 19 |
| Hyc65 | 101 | 80 | 125 | 38 | 7 | 20 |
| Hyc66 | 61 | 40 | 71 | 21 | 4 | 11 |
| Hyc67 | 45 | 32 | 46 | 14 | 3 | 8 |

| Sub-watershed | Deer | Raccoon | Muskrat | Beaver | Wild Turkey | Goose |
|---|---|---|---|---|---|---|
| Hyc68 | 75 | 48 | 167 | 50 | 7 | 20 |
| Hyc69 | 96 | 61 | 212 | 64 | 8 | 25 |
| Hyc7 | 89 | 71 | 73 | 22 | 5 | 15 |
| Hyc70 | 64 | 38 | 140 | 42 | 6 | 16 |
| Hyc71 | 62 | 47 | 90 | 27 | 4 | 13 |
| Hyc8 | 120 | 97 | 140 | 42 | 8 | 23 |
| Hyc9 | 73 | 64 | 49 | 15 | 4 | 12 |
| LBC1 | 0 | 0 | 1 | 0 | 0 | 0 |
| LBC10 | 7 | 2 | 6 | 2 | 0 | 1 |
| LBC11 | 7 | 3 | 12 | 3 | 1 | 2 |
| LBC12 | 20 | 4 | 12 | 4 | 1 | 3 |
| LBC13 | 8 | 3 | 11 | 3 | 1 | 2 |
| LBC14 | 5 | 2 | 8 | 2 | 0 | 1 |
| LBC2 | 1 | 1 | 4 | 1 | 0 | 1 |
| LBC3 | 1 | 1 | 2 | 1 | 0 | 0 |
| LBC4 | 1 | 1 | 5 | 2 | 0 | 1 |
| LBC5 | 5 | 2 | 3 | 1 | 0 | 1 |
| LBC6 | 12 | 5 | 10 | 3 | 1 | 3 |
| LBC7 | 16 | 8 | 14 | 4 | 1 | 4 |
| LBC8 | 11 | 4 | 13 | 4 | 1 | 3 |
| LBC9 | 7 | 2 | 5 | 2 | 0 | 1 |

# APPENDIX C. ABBREVIATIONS AND GLOSSARY

# Abbreviations

AVMA: American Veterinary Medical Association
BASINS: Better Assessment Science Integrating Point and Non-point Sources
BMP: Best Management Practice
DEM: Digital Elevation Model
EPA: Environmental Protection Agency
HSPEXP: Expert System for Calibration of the Hydrological Simulation Program-FORTRAN
HSPF: Hydrologic Simulation Program-Fortran
HUC: Hydrologic Unit Code
LA: Load Allocation
NASS: National Agricultural Statistics Service
NCDC: National Climatic Data Center
NHD: National Hydrography Dataset
NLCD: National Land Coverage Database
NOAA: National Oceanic and Atmospheric Association
NPDES: National Pollution Discharge Elimination System
NRCS: Natural Resources Conservation Service
MOS: Margin of Safety
SSURGO: Soil Survey Geographic
SWCB: State Water Control Board
TMDL: Total Maximum Daily Load
TRMM: Tropical Rainfall Measuring Mission
USGS: U.S. Geological Survey
VADCR: Virginia Department of Conservation and Recreation
VADEQ: Virginia Department of Environmental Quality
VADGIF: Virginia Department of Game and Inland Fisheries
VDH: Virginia Department of Health
VDMME: Virginia Department of Mines, Minerals, and Energy
VPDES: Virginia Pollutant Discharge Elimination System
VSMP: Virginia Stormwater Management Program
UAA: Use Attainability Analysis
USDA: United States Department of Agriculture
WLA: Wasteload Allocation
WQMIRA: Water Quality Monitoring, Information, and Restoration Act

# Glossary

**303(d).** A section of the Clean Water Act of 1972 requiring states to identify and list water bodies that do not meet the states' water quality standards.

**Allocations.** That portion of receiving water's loading capacity attributed to one of its existing or future pollution sources (non-point or point) or to natural background sources. (A wasteload allocation [WLA] is that portion of the loading capacity allocated to an existing or future point source, and a load allocation [LA] is that portion allocated to an existing or future non-point source or to natural background levels. Load allocations are best estimates of the loading, which can range from reasonably accurate estimates to gross allotments, depending on the availability of data and appropriate techniques for predicting loading.)

**Ambient water quality.** Natural concentration of water quality constituents prior to mixing of either point or non-point source load of contaminants. Reference ambient concentration is used to indicate the concentration of a chemical that will not cause adverse impact on human health.

**Anthropogenic.** Pertains to the [environmental] influence of human activities.

**Bacteria.** Single-celled microorganisms. Bacteria of the coliform group are considered the primary indicators of fecal contamination and are often used to assess water quality.

**Best management practices (BMPs).** Methods, measures, or practices determined to be reasonable and cost-effective means for a landowner to meet certain, generally non-point source, pollution control needs. BMPs include structural and nonstructural controls and operation and maintenance procedures.

**Clean Water Act (CWA).** The Clean Water Act (formerly referred to as the Federal Water Pollution Control Act or Federal Water Pollution Control Act Amendments of 1972), Public Law 92-500, as amended by Public Law 96-483 and Public Law 97-117, 33 U.S.C. 1251 et seq. The Clean Water Act (CWA) contains a number of provisions to restore and maintain the quality of the nation's water resources. One of these provisions is section 303(d), which establishes the TMDL program.

**Concentration.** Amount of a substance or material in a given unit volume of solution; usually measured in milligrams per liter (mg/L) or parts per million (ppm).

**Contamination.** The act of polluting or making impure; any indication of chemical, sediment, or biological impurities.

**Critical condition.** The critical condition can be thought of as the "worst case" scenario of environmental conditions in the waterbody in which the loading expressed in the TMDL for the pollutant of concern will continue to meet water quality standards. Critical conditions are the combination of environmental factors (e.g., flow, temperature, etc.) that results in attaining and maintaining the water quality criterion and has an acceptably low frequency of occurrence.

**Designated uses.** Those uses specified in water quality standards for each waterbody or segment whether or not they are being attained.

**Domestic wastewater.** Also called sanitary wastewater, consists of wastewater discharged from residences and from commercial, institutional, and similar facilities.

**Drainage basin.** A part of a land area enclosed by a topographic divide from which direct surface runoff from precipitation normally drains by gravity into a receiving water. Also referred to as a watershed, river basin, or hydrologic unit.

**Existing use.** Use actually attained in the waterbody on or after November 28, 1975, whether or not it is included in the water quality standards (40 CFR 131.3).

**Fecal Coliform.** Indicator organisms (organisms indicating presence of pathogens) associated with the digestive tract.

**Geometric mean.** A measure of the central tendency of a data set that minimizes the effects of extreme values.

**GIS.** Geographic Information System. A system of hardware, software, data, people, organizations and institutional arrangements for collecting, storing, analyzing and disseminating information about areas of the earth. (Dueker and Kjerne, 1989)

**Infiltration capacity.** The capacity of a soil to allow water to infiltrate into or through it during a storm.

**Interflow.** Runoff that travels just below the surface of the soil.

**Loading, Load, Loading rate.** The total amount of material (pollutants) entering the system from one or multiple sources; measured as a rate in weight per unit time.

**Load allocation (LA).** The portion of a receiving waters loading capacity attributed either to one of its existing or future non-point sources of pollution or to natural background sources. Load allocations are best estimates of the loading, which can range from reasonably accurate estimates to gross allotments, depending on the availability of data and appropriate techniques for predicting the loading. Wherever possible, natural and non-point source loads should be distinguished (40 CFR 130.2(g)).

**Loading capacity (LC).** The greatest amount of loading a water body can receive without violating water quality standards.

**Margin of safety (MOS).** A required component of the TMDL that accounts for the uncertainty about the relationship between the pollutant loads and the quality of the receiving water body (CWA section 303(d)(1)©). The MOS is normally incorporated into the conservative assumptions used to develop TMDLs (generally within the calculations or models) and approved by EPA either individually or in state/EPA agreements. If the MOS needs to be larger than that which is allowed through the conservative assumptions, additional MOS can be added as a separate component of the TMDL (in this case, quantitatively, a TMDL = LC = WLA + LA + MOS).

**Mean.** The sum of the values in a data set divided by the number of values in the data set.

**Monitoring.** Periodic or continuous surveillance or testing to determine the level of compliance with statutory requirements and/or pollutant levels in various media or in humans, plants, and animals.

**Narrative criteria.** Non-quantitative guidelines that describe the desired water quality goals.

**Non-point source.** Pollution that originates from multiple sources over a relatively large area. Non-point sources can be divided into source activities related to either land or water use including failing septic tanks, improper animal-keeping practices, forest practices, and urban and rural runoff.

**Numeric targets.** A measurable value determined for the pollutant of concern, which, if achieved, is expected to result in the attainment of water quality standards in the listed waterbody.

**Point source.** Pollutant loads discharged at a specific location from pipes, outfalls, and conveyance channels from either municipal wastewater treatment plants or industrial waste treatment facilities. Point sources can also include pollutant loads contributed by tributaries to the main receiving water waterbody or river.

**Pollutant.** Dredged spoil, solid waste, incinerator residue, sewage, garbage, sewage sludge, munitions, chemical wastes, biological materials, radioactive materials, heat, wrecked or discarded equipment, rock, sand, cellar dirt, and industrial, municipal, and agricultural waste discharged into water. (CWA section 502(6)).

**Pollution.** Generally, the presence of matter or energy whose nature, location, or quantity produces undesired environmental effects. Under the Clean Water Act, for example, the term is defined as the man-made or man-induced alteration of the physical, biological, chemical, and radiological integrity of water.

**Poultry Litter.** A material used as bedding in poultry operations. Common litter materials are wood shavings, sawdust, peanut hulls, shredded sugar cane, straw, and other dry, absorbent, low-cost organic materials. After use, the litter consists primarily of poultry manure, but also contains the original litter material, feathers, and spilled feed.

**Privately owned treatment works.** Any device or system that is (a) used to treat wastes from any facility whose operator is not the operator of the treatment works and (b) not a publicly owned treatment works.

**Public comment period.** The time allowed for the public to express its views and concerns regarding action by EPA or states (e.g., a Federal Register notice of a proposed rule-making, a public notice of a draft permit, or a Notice of Intent to Deny).

**Publicly owned treatment works (POTW).** Any device or system used in the treatment (including recycling and reclamation) of municipal sewage or industrial wastes of a liquid nature that is owned by a state or municipality. This definition includes sewers, pipes, or other conveyances only if they convey wastewater to a POTW providing treatment.

**Raw sewage.** Untreated municipal sewage.

**Receiving waters.** Creeks, streams, rivers, lakes, estuaries, ground-water formations, or other bodies of water into which surface water and/or treated or untreated waste are discharged, either naturally or in man-made systems.

**Riparian areas.** Areas bordering streams, lakes, rivers, and other watercourses. These areas have high water tables and support plants that require saturated soils during all or part of the year. Riparian areas include both wetland and upland zones.

**Riparian zone.** The border or banks of a stream. Although this term is sometimes used interchangeably with floodplain, the riparian zone is generally regarded as relatively narrow compared to a floodplain. The duration of flooding is generally much shorter, and the timing less predictable, in a riparian zone than in a river floodplain.

**Runoff.** That part of precipitation, snowmelt, or irrigation water that runs off the land into streams or other surface water. It can carry pollutants from the air and land into receiving waters.

**Septic system.** An on-site system designed to treat and dispose of domestic sewage. A typical septic system consists of a tank that receives waste from a residence or business and a drain field or subsurface absorption system consisting of a series of percolation lines for the disposal of the liquid effluent. Solids (sludge) that remain after decomposition by bacteria in the tank must be pumped out periodically.

**Sewer.** A channel or conduit that carries wastewater and storm water runoff from the source to a treatment plant or receiving stream. Sanitary sewers carry household, industrial, and commercial waste. Storm sewers carry runoff from rain or snow. Combined sewers handle both.

**Slope.** The degree of inclination to the horizontal. Usually expressed as a ratio, such as 1:25 or 1 on 25, indicating one unit vertical rise in 25 units of horizontal distance, or in a decimal fraction (0.04), degrees (2 degrees 18 minutes), or percent (4 percent).

**Stakeholder.** Any person with a vested interest in the TMDL development.

**Surface area.** The area of the surface of a waterbody; best measured by planimetry or the use of a geographic information system.

**Surface runoff.** Precipitation, snowmelt, or irrigation water in excess of what can infiltrate the soil surface and be stored in small surface depressions; a major transporter of non-point source pollutants.
**Surface water.** All water naturally open to the atmosphere (rivers, lakes, reservoirs, ponds, streams, impoundments, seas, estuaries, etc.) and all springs, wells, or other collectors directly influenced by surface water.

**Topography.** The physical features of a geographic surface area including relative elevations and the positions of natural and man-made features.

**Total Maximum Daily Load (TMDL).** The sum of the individual wasteload allocations (WLAs) for point sources, load allocations (LAs) for non-point sources and natural background, plus a margin of safety (MOS). TMDLs can be expressed in terms of mass per time, toxicity, or other appropriate measures that relate to a state's water quality standard.

**Virginia Pollutant Discharge Elimination System (NPDES).** The national program for issuing, modifying, revoking and re-issuing, terminating, monitoring, and enforcing permits, and imposing and enforcing pretreatment requirements, under sections 307, 402, 318, and 405 of the Clean Water Act.

**Wasteload allocation (WLA).** The portion of a receiving waters' loading capacity that is allocated to one of its existing or future point sources of pollution. WLAs constitute a type of water quality-based effluent limitation (40 CFR 130.2(h)).

**Wastewater.** Usually refers to effluent from a sewage treatment plant. See also **Domestic wastewater**.

**Wastewater treatment.** Chemical, biological, and mechanical procedures applied to an industrial or municipal discharge or to any other sources of contaminated water to remove, reduce, or neutralize contaminants.

**Water quality.** The biological, chemical, and physical conditions of a waterbody. It is a measure of a waterbody's ability to support beneficial uses.

**Water quality criteria.** Levels of water quality expected to render a body of water suitable for its designated use, composed of numeric and narrative criteria. Numeric criteria are scientifically derived ambient concentrations developed by EPA or states for various pollutants of concern to protect human health and aquatic life. Narrative criteria are statements that describe the desired water quality goal. Criteria are based on specific levels of pollutants that would make the water harmful if used for drinking, swimming, farming, fish production, or industrial processes.

**Water quality standard.** Law or regulation that consists of the beneficial designated use or uses of a waterbody, the numeric and narrative water quality criteria that are necessary to protect the use or uses of that particular waterbody, and an antidegradation statement.

**Watershed.** A drainage area or basin in which all land and water areas drain or flow toward a central collector such as a stream, river, or lake at a lower elevation.